STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SIGNAL, LIGHTING AND ELECTRICAL SYSTEMS DESIGN GUIDE

FIFTH EDITION
April, 2007




TRAFFIC OPERATIONS PROGRAM
OFFICE OF ITS PROJECTS AND STANDARDS
ELECTRICAL SYSTEMS BRANCH

ACKNOWLEDGEMENTS

Appreciation is expressed for the development of the Signal, Lighting and Electrical Systems Design Guide by incorporating the previous Signal and Lighting Design Guide, District 03 Electrical Design Guide, studies by ITE, FHWA, and NCHRP. Thanks to the following individuals for their input and contributions which made this Design Guide possible.

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PLANS

1.0 GENERAL

This Design Guide describes typical practices for new or modified Traffic Control Signals, Lighting, Sign Illumination and Intelligent Transportation System / Transportation Management System (ITS/TMS) installations statewide. The Guide is a supplement to the Highway Design Manual, California Manual on Uniform Traffic Control Devices (California MUTCD), Standard Plans, Standard Specifications, Standard Special Provisions, and other current related department policies.

Deviations are allowed based on informed engineering decisions. The designer should contact the District Electrical Project Engineer (DEPE) or their project engineer assigned representative to determine whether there are any special requirements for a project.

1.1 PLAN SHEETS

The plan sheets shall be according to Plans Preparation Manual, Section 2 – Project Plans. The manual is available at:
http://www.dot.ca.gov/hq/esc/oe/project_plans/drafting/dpmanual.pdf

The scale of the plans shall be:

Table 1. Scale of Plans

Type	Scale
Signal and Lighting	1”=20’
Lighting and Sign Illumination	1”=50’
ITS/TMS and Fiber Optics	1”=50’

There should be only one set of general notes applicable to an entire project or special symbols on a project, preferably all on one sheet of the electrical plans. Project notes should appear on each plan sheet to which they apply and the same project note shall have that same number on every plan sheet upon which it appears. Only those project notes applicable to a sheet will appear on that sheet.

Abbreviations, standard notes or symbols shown on the Standard Plans shall not be redefined on a project. Any project note or symbols not defined in the Standard Plans should be defined. In no case should the same project note or symbol be defined differently on separate sheets of the same project.

Where signal installations are to be modified, it is desirable that the plans include a separate plan of the existing system as well as a plan showing the modifications.

When the existing system is shown on the same sheet as the proposed signal plan, the existing system may be shown on a separate sheet using 1”=50’ scale. Refer to page 2-2.23 of the Drafting and Plans Manual for approved plan sheet titles.

The title of each sheet of electrical plans shall be the bid item, a portion of the bid item or the combination of bid items.

Permit projects should indicate the applicable Standard Plans on the project plans or in the Special Provisions.

Utility plans showing high and low risk utilities, signs, stripe and pavement plans shall be provided. Stationing, Right of Way, Stage Construction, Cross-section, Curb Ramp and sidewalk information should be provided.

The proposed electrical work for electrical system/facility shall be shown on one or more sheets. Designer shall also include the following:

a) All existing electrical system/facilities (including detection system) within the project limits even if they are not effected by the Construction activities.
b) Include all Standard Special Provisions (SSP) pertaining to the electrical work involved, including the specifications for “Maintaining Existing Traffic Management System Elements during Construction.”

Generate a notice to the Construction with a copy to Traffic Operations (electrical) representative(s), in the Resident Engineer (RE) pending file, to involve Traffic Operations (electrical) representative(s) and the Contractor for the pre & post construction meeting for operational status check of all electrical systems (including detection system.)

1.2 STAGING PLANS

To insure continuous reliable operation of all TMS elements in the State highway system during all stages of project construction, the continuity of existing TMS elements shall be accounted for in the design of all projects.

Staging plans for the TMS element(s) including detection system will be required if the duration for the outages exceeds as specified in the specifications for “Maintaining Existing Traffic Management System Elements during Construction.”

If construction activities cause existing ITS element(s) to be inoperable for a longer time period and/or the spacing between stations is other than the specified criteria, then temporary operation (such as temporary detection) shall be implemented in the design.

2.0 SIGNAL AND LIGHTING

For typical signal and lighting design, see Sheets E-1 and E-2.
Some local agencies may require special (e.g. decorative) signal and lighting standards and/or special paint on standards. The designer should coordinate with Structures and/or Maintenance for review and approval. A maintenance agreement shall be processed and shall be in place covering 100 percent of the additional cost over the standard equipment at the local agency's expense, including maintenance of the equipment.

2.1 CONTROLLER UNIT

The controller unit shall be a Model 170E or 2070 for State highway locations. The cabinet shall be a Model 332 for intersection control, and a Model 334 for ramp metering. For the furnishing of controller assembly on jointly funded projects, refer to the Model 170/2070 Controller Assembly Cost Participation Policy, dated August 10, 1988. (See Appendix A) If using the Model 2070 controller unit, refer to Transportation Electrical Equipment Specifications (TEES), August 16, 2002 and Erratum 2, June 2004. The TEES is available online at: http://www.dot.ca.gov/hq/traffops/elecsys/index.htm

Lateral placement of signal supports and cabinets shall comply with the California MUTCD, Section 4D.19. The California MUTCD is available online at: www.dot.ca.gov/hq/traffops/signtech/mutcdsupp/ca_mutcd.htm

2.2 SIGNAL AND LIGHTING STANDARDS

For signal and lighting standards, refer to Standard Plans ES-6A through ES-7N.

Median installation of traffic signal and lighting standards should be avoided. For location of signal faces, refer to California MUTCD, Section 4D.15.

Signal mastarm lengths up to 65 ft are available. Signal mastarm length greater than 65 ft must be designed and approved by Headquarters (HQ) Structures Special Design Branch.

Guard posts should not be used, except to protect equipment from vehicles in parking lots.

See the following example for selecting a signal and lighting standard for a nonstandard signal or sign and to compare wind moments about the signal arm support or pole.

This is ONLY an example, the designer shall contact HQ Structures Special Design Branch for their nonstandard design.

Selecting a Signal Standard for a nonstandard Signal or Sign. Select a signal arm from the Standard Plans that is similar to your signal layout. Look for a standard that has an equal or greater number of signs or signals on the mastarm. Signal arm loading should be carefully selected to meet current and any future needs. Any special loading should be reviewed and approved by HQ Structures Special Design Branch.

EXAMPLE: Compare Standard Plan moments with those of your design. Your design moments should not exceed the Standard Plan moments.

Standard Plan **Your Design**

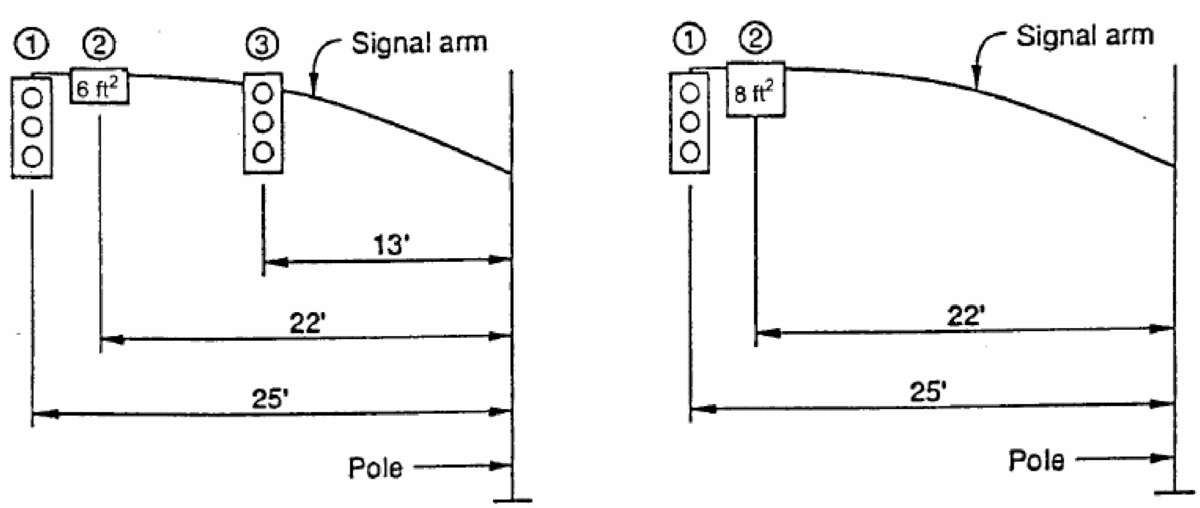


Figure 1. Signal Standard 18-3-100, with 25 ft Arm

Standard Plan

(1) Projected Area = 10.24 ft²
Weight = 55 lb.

(2) Projected Area = 6 ft²
Weight = 44 lb.

(3) Projected Area = 10.24 ft²
Weight = 55 lb.

Your Design

(1) Projected Area = 10.24 ft²
Weight = 55 lb.

(2) Projected Area = 8 ft²
Weight = 44 lb.

Compare Wind Moments about Signal Arm Support or Pole

	Standard Plan		**Your Design**	
	18-3-80 Signal Arm 25 ft		18-3-80 Signal Arm 25 ft	
Sig./Sign No.	Project Area Arm	Moment	Projected Area	Moment
1.	10.24 ft² X 25 ft	= 256	10.24 ft² X 25 ft	= 256
2.	6 ft² X 22 ft	= 132	8 ft² X 22 ft	= 176
3.	10.24 ft² X 13ft	= 133		
	total	= 521	total	= 432

Since 432 is less than 521, your design is OK for the wind loading.

Compare Dead Load (weight) Moments about Signal Support

	Standard Plan		**Your Design**	
Sig./Sign No.	Weight Arm	Moment	Weight Arm	Moment
1.	55 lb. X 25 ft	= 1375	55 lb. X 25 ft	= 1375
2.	44 lb. X 22 ft	= 968	44 lb. X 22 ft	= 968
3.	55 lb. X 13 ft	= 715		
	total	= 3058	total	= 2343

Since 2343 is less than 3058, your design is OK for the given weight.

The following table lists the projected Areas and Weights for the traffic signal and sign.

Table 2. Projected Areas and Weights for Traffic Signal and Sign

Signal and Sign	Projected Area	Weight
3-Section Signal	10.24 ft²	55 lb *
4-Section Signal	12.37 ft²	64 lb
5-Section Signal	14.53 ft²	80 lb
Lt Turn Flat Sign (not illuminated)	14.10 ft²	43 lb *
1.8-meter Internally Illuminated Street Sign	11.0 ft²	65 lb
2.4-meter Internally Illuminated Street Sign	14.64 ft²	85 lb
3M Program Visibility Head	8.75 ft²	55 lb

* Use for Standard Plan unless shown otherwise

2.3 CONDUCTORS

The designer shall consult the Electrical Design Branch Chief (EDBC) regarding the use of individual conductors or conductor cables for a project.

Only interconnect conductors between coordinated signal systems shall be allowed to occupy the same conduits, pull boxes (PB) or raceway.

Where new conductors are to be added to an existing conduit:

- Replace any existing conductors that have Thermoplastic High Heat Resistant Nylon (THHN) insulation by conductors with insulation as specified in the Standard Specifications and Standard Special Provisions (SSPs).
- All other existing conductors should be examined for deterioration and may be considered for replacement.

When the existing conductors are reused, the number and size should be indicated on the Plans. Conductors to be added or removed should also be noted.

Lighting and Flashing Beacon conductors should not enter a controller cabinet.

Existing aluminum conductors should be replaced with the appropriately sized copper conductor.

Overhead service drop conductors shall be equal or bigger than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

2.3.1 DETERMINING ADEQUATE CONDUCTOR SIZE

Voltage Drop (V_D) calculation should be performed for all branch and feeder circuits to determine if the conductor size is adequate. The National Electrical Code (NEC) allows a maximum voltage drop of:

- branch circuit: 3%
- feeder circuit: 2%
- entire circuit: 5%

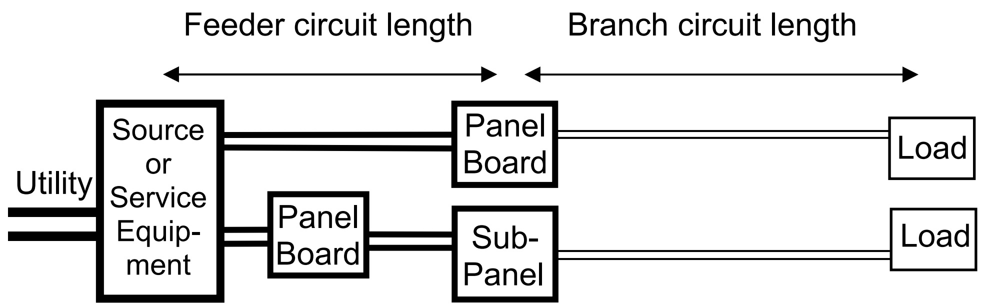


Figure 2. Voltage Drop Circuit

Where electric loads cause V_D to exceed the allowable % V_D limits (e.g. due to long circuit lengths) consider <u>one</u> of the following:

- increase the conductor size to a point until it is no longer economical (be sure to increase the size of equipment grounding conductor proportionately, Article 250-122B of NEC)
- increase the voltage by providing a step up and step down transformers
- provide a buck/boost transformer where applicable

Also, see “Circuit Lengths” in Section 4 of this Design Guide.

2.3.2 VOLTAGE DROP CALCULATION FOR SINGLE PHASE

For single phase: $V_D = 2 \times D \times I_L \times Z_{effective}$

$$\% \, V_D = \frac{V_D}{\text{Voltage}} \times 100$$

Circuit length, D is one way circuit length in feet

Line current, $I_L = \dfrac{P\ (\text{watt})}{V \times \text{Cos}\,\theta}$

Effective impedance, $Z_{effective} = (R \cdot \text{Cos}\,\theta + X \cdot \text{Sin}\,\theta)$

For the values of Resistance (R) and Reactance (X), refer to chapter 9, table 9 of NEC. Note, $Z_{effective}$ is calculated per 1000 ft.

Power factor, $\text{Cos}\,\theta = \text{p.f.}$

EXAMPLE: Calculate voltage drop for single phase

A No. 12 AWG conductor is selected from table 310.16 of NEC, based on design requirement for 75º C, type THHW Copper wires in PVC conduit with a 25 Amp load. The applied voltage is 120 V. D is 150 ft for the branch circuit, 1020 W @ power factor (p.f.) of 0.85. What is the % V_D ?

Power factor, $\text{Cos}\,\theta = 0.85$

$\theta = 31.79^{o}$, Then $\text{Sin}\,\theta = 0.527$

Find R and X, R=2 and X=0.054, for 1000' per NEC

$Z_{effective}$, $Z_{effective/1000} = (R \cdot \text{Cos}\,\theta + X \cdot \text{Sin}\,\theta)$

$Z_{effective\,/1000'} = (2 \cdot 0.85 + 0.054 \cdot 0.527) \quad \Rightarrow 1.728\ \Omega$

Line Current, $I_L = \dfrac{1020\,W}{120\,V \cdot 0.85} \quad \Rightarrow 10\,\text{amps}$

Voltage Drop $V_D = 2 \times D \times I_L \times Z_{effective}$

$V_D = 2 \cdot \dfrac{150\,ft}{1000\,ft} \cdot 10\,\text{amp} \cdot 1.728\,\Omega \quad \Rightarrow 5.18\ V$

Percent Voltage Drop $\%\ V_D = \dfrac{5.18\ V}{120\ V} \times 100 \quad \Rightarrow 4.32\%$

Since 4.32% is more than the allowable 3% V_D, it is unacceptable. One of the three possible solutions mentioned earlier is to increase the conductor size.

The next larger size is 10 AWG conductor, where R=1.2, X=0.05 per NEC.

For 10 AWG, $Z_{effective\,/1000'} = (1.2 \cdot 0.85 + 0.05 \cdot 0.527) \quad \Rightarrow 1.05\ \Omega$

The line current will remain 10 amps and the new calculated V_D is 3.15 V.

Then, $\%\ V_D = \dfrac{3.15\ V}{120\ V} \times 100 = 2.62\%$

Since 2.62% is less than the allowable 3% VD, the 10 AWG conductor size is adequate for the mentioned parameters.

2.3.3 VOLTAGE DROP CALCULATION FOR 3-Ø

For three phase: $V_D = \sqrt{3} \times D \times I_L \times Z_{effective}$

$$\%V_D = \frac{V_D}{Voltage} \times 100$$

Circuit length, D is a one way circuit length in feet

Line current, $I_L = \dfrac{P_{line}(watt)}{\sqrt{3} \times V_{line} \times Cos\,\theta}$

Effective impedance, $Z_{effective} = (R \cdot Cos\,\theta + X \cdot Sin\,\theta)$

For the values of R and X, refer to chapter 9, table 9 of NEC. Note, Zeffective is calculated per 1000 ft.

2.4 CONDUIT

There shall be at least two conduits of 3” size entering a controller cabinet.

Size and number of conductors of any conduit runs not shown in the Conductor and Conduit Schedule should be indicated on the plans.

Maximum allowable conduit fill is 26% for new conduit and 35% for existing conduit.

For modification projects, all existing conduits affected by a modification should be examined to see if they should be replaced. When existing Type 1 conduits are more than 10 years old and are in a corrosive environment, the designer should consider replacement of the conduits. Type 3 conduit should be used for most underground installation, even in a foundation.

2.5 PULL BOXES

Pull boxes should be No. 5, minimum.

A No. 6 pull box should be used when:

a) the pull box is adjacent to the controller cabinet
b) four or more conduits enter the pull box

When the Service Equipment Enclosure (SVE) can be installed in close proximity to the controller cabinet, the load side conduit(s) from the SVE may be installed directly to the No. 6 pull box in front of the controller cabinet.

Pull boxes should not be placed:

a) in painted medians
b) in paved shoulder
c) in the roadway or inside traveled way (Type A detector handholes are special cases, see DETECTORS)
d) within the boundaries of a curb ramp

Pull boxes shall be the non-Portland Cement Concrete (PCC) types when in unpaved areas, or where the pull box is not adjacent to a signal/lighting standard. A pull box marker should be placed at each pull box unpaved areas or where the pull box is not adjacent to a signal/lighting standard. Markers should comply with Type K-2 Marker as shown on Standard Plan Sheet A73A, except that no reflectorizing will be required. A non-reflective green identification strip shall be applied to each marker.

A separate item should be included in overlay and rehab projects of “Adjust Pull Boxes to Grade.” When adjusting pull boxes to grade, adjusting conduits to grade shall be considered. (The unit should be “Each” versus “Lump Sum.” A quantity can be estimated from As-Builts.) If a quantity can not be estimated, state in the Special Provisions that adjusting pull boxes to grade shall be paid for as extra work.

If the pull box is located where it can be subject to incidental traffic, it should be specified with a traffic cover.

2.6 DETECTORS

See sections "Plan Sheets," and "Staging Plans" of this design guide when detectors maybe effected by a project. For inductive loops and video imaging vehicle detection system (VIVDS), see below.

2.6.1 INDUCTIVE LOOPS

The main street should have advance detectors. Advance detection should also be considered on the side street if the vehicle speed is 30 mph or greater.

Advance detectors should have a separate Detector Lead-in Cable (DLC) per loop designation and should be located as follows (for speeds between the values shown, use the next higher value):

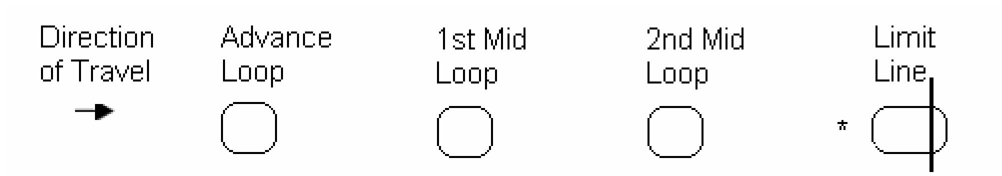


Figure 3. Advance and Mid Loop Detectors
* Front Detection type/location per District guidelines

Table 3. Speed and Loop Distance for Advance Detection

Approach Speed, mph	Distance Of Advance Loop From Limit Line, ft *	Distance Of Intermediate Loop From Limit Line, ft	
		1st Mid Loop	2nd Mid Loop
25	105**		
30	140		
35	185		
40	230	113**	
45	285	153	
50	345	198	
55	405	244	83**
60***	475	300	125
65***	550	359	168
70***	630	425	220

* Per Chapter 4D, California MUTCD
** Intermediate loop may or may not be needed, consult the Electrical Design Branch Chief.
*** Two mid detector loops per lane are recommended.

The placement of intermediate loop detectors from the limit line is obtained by subtracting the distance traveled in 2 seconds at that speed, from the distance of advance loop detectors.

The Advance loop distance is given by California MUTCD:

Detector Setback = Deceleration Distance + Reaction Distance

Detector Setback = $\frac{V^2}{2 \cdot d} + V \cdot T$

Where, deceleration ratio d = 10 ft/sec^2

Where, reaction time t = 1 sec

For example, at 55 mph the advance loop distance:

55 mph (5280 ft/mi) x (1 hr/3600 s) = 80.6 ft/s

Detector Setback = $\frac{(80.6\,\text{ft}/\text{sec})^2}{2 \cdot (10\,\text{ft}/\text{sec}^2)} + (80.6\,\text{ft}/\text{sec}) \cdot (1\,\text{sec})$

Detector Setback = 405 ft

The distance for the 1st Mid loop from the limit line:

405 ft – 80.6 ft/s x 2 sec = 244 ft

The distance for the 2nd Mid loop from the limit line:

244 ft – 80.6 ft/sec x 2 sec = 83 ft

Approach speed is the posted speed limit, or the prima facie in the absence of the posted speed. Where approaching speed exceeds 70 mph, consult the Electrical Design Branch Chief.

Type A or Type E detectors may be used, but a combination of Type A and Type E is not allowed. The use of detector handholes should be considered in all paved areas adjacent to the curb. The detector handhole shall be Type A.

Where there is no raised median, the Type A detector handhole for the left turn pocket should be placed in the center of the painted island or on the center stripe.

Type D loops are recommended for bicycle detection. Bicycle push buttons are advised for use where a bicycle lane is present. The designer is advised to investigate intersection/traffic needs during the preliminary design. A separate front type D loop should be addressed for left turn lanes where bicycle traffic is expected.

The designer should consider preformed loops for new bridges. The designer shall consult the Electrical Design Branch Chief regarding the use of a preformed loop detector on a project. When possible, badly damaged pavement should be replaced before installing loop detectors.

When inductive loops are to be installed by cutting into an existing bridge deck, the designer should submit electrical plans for review and approval by HQ Structures Special Design Branch.

The designer shall consult the District Signal Operations Engineer regarding the distance for advance detection for signalized off-ramps or when alternative detection other than inductive loops is considered.

The designer should consider installing departing loops for count data. Consult the traffic Census Coordinator for assistance in this determination.

2.6.2 VIDEO IMAGING VEHICLE DETECTION SYSTEMS (VIVDS)

The design engineer should refer to the “Intersection Video Detection Field Handbook” and “Intersection Video Detection Manual” report, on the National Technical Information Service Website www.ntis.gov

2.7 EQUIPMENT NEAR GASOLINE STATIONS

Controller cabinets, service equipment enclosures, poles and pull boxes shall not be located within 20 ft from any gas pump, 10 ft from any underground tank fill opening nor 5 ft from any underground tank vent opening. Any conduit within these limits shall be Type 1 or 2 conduit. If it is impossible to adjust equipment locations to place them outside these limits, then the conduit must be sealed in accordance with the NEC. (Refer to Article 514.)

2.8 EXISTING EQUIPMENT

Where installations are to be modified, it is the responsibility of the designer to check with the Electrical Design Branch Chief and the Electrical Maintenance Supervisor to see whether any existing equipment to be removed and not reused should be salvaged.

The address to deliver the salvaged equipment shall be specified in the special provisions.

2.9 OVERHEAD CLEARANCE

The minimum radial clearance between overhead utility lines and new or relocated State signal or lighting equipment (e.g. standard, mastarms and luminaire) shall be as follows:

Table 4. Minimum Overhead Clearance

Voltage (phase to phase)	Minimum Clearance, ft
Up to 600	3.3
Over 600 to 50,000	10
Over 50,000 to 75, 000	11
Over 75,000 to 125,000	13
Over 125,000 to 175,000	15
Over 175,000 to 250,000	17
Over 250,000 to 370,000	21
Over 370,000 to 550,000	27
Over 550,000 to 1,000,000	42

For additional information relating to overhead clearances, refer to California Code of Regulations, Title 8, Section 2946 “Provisions for Preventing Accidents Due to Proximity of Overhead Lines.” www.dir.ca.gov/title8/2946.html

2.10 SERVICE

Service equipment enclosures and metering equipment shall meet the requirements of the service utility. Deviations from the service wiring diagram shown on the Standard Plans shall be shown on the project plans. The name of the utility must appear on the plans adjacent to the service point. When a service-wiring diagram consists of multiple branch circuits, a main breaker with proper rating shall be provided.

The main busses and terminal lugs of service equipment enclosures for the Model 500 changeable message signs (CMS) shall be rated for 200 A (Xenon or LED); and the ground wire shall be No. 2 AWG bare copper. Please refer to Transportation Electrical Equipment Specifications (TEES), Chapter 8 for all CMS, related information.

Unless directed otherwise by the District Electrical Project Engineer, the service equipment enclosure should be located a minimum of 10 ft from the controller cabinet.

Where another agency wants to install non-State maintained equipment (such as a separate cabinet with sampling detectors or other equipment) at a State-maintained system, the equipment should have separate service.

Arrangements shall be made with the service utility to establish or provide service points for the installations during the design stage or when the preliminary plans are completed. It is recommended to field review the proposed service point locations with a utility representative. Three sets of plans (minimum) with proposed service points indicated shall be sent to utility for approval, and a copy of the correspondence should be kept in file.

Please refer to other requirements listed in the “Policy on High and Low Risk Underground Facilities within Highway Rights of Way.” See appendix H for the web address.

2.11 UTILITY SERVICE

For telephone and electrical utilities, see the following.

2.11.1 TELEPHONE SERVICE

The designer shall make a site visit and propose a service location closest to the proposed controller cabinet. The designer shall also obtain their District telephone demarcation cabinet number from the District Telephone Cabinet (TC) Coordinator (DTCC). When preliminary design is completed, a letter of request (indicating TC number) and plans showing the telephone demarcation/conduit/cable shall be sent to the service utility to establish or provide service points during the design stage. A copy of the letter of request shall be sent to the District Telephone Service Coordinator. When the telephone service company appoints a service representative engineer for the project, it is required to field review the proposed service point location with the utility representative and agree on service locations shown on the X/Y form provided by the utility company. The designer shall then sign and send the X/Y forms to the utility company and keep a copy in the RE file. (Use your District's established forms, see an example in Appendix J). The designer shall submit the RE file to the District/Region Division of Construction by the Ready to List (RTL) date. When a telephone is to be installed during construction, the RE shall contact District Telephone Service coordinator who informs the utility company to activate the service. (Use your District's established process flow, see an example in Appendix N for the process flow chart.)

2.11.2 ELECTRICAL SERVICE

Construction has the responsibility to order the service connection. However, the designer should first investigate for existing available service in the area before starting the process and fill out as much of the form as possible.

During the design stage, the electrical designer shall establish a unique, 15-digit Caltrans ID Number (CTID No.) for each electrical service point. The CTID number shall be confirmed with the district signal and lighting coordinator (DSLC) and shall be shown on the contract plans.

The CTID number shall follow the format shown below:

XX	District (2-digit numeric, zero fill – 01 thru 12)
XX	County (2-digit numeric, zero fill – 01 thru 58)
XXX	Route (3-digit numeric, zero fill – 001 thru 999)
X	Alternate (R = realign, O = overlap, zero for no alternate)
XXX.XXX	Postmile (zero fill)
X	Metered (M = metered service, U = unmetered service)

The electrical designer may need to check for utility provider special requirements on SVE, if so desired. Service equipment enclosures and metering equipment shall meet the requirements of the service utility. If the service utility requires an Electrical Utility Service Equipment Requirement Code (EUSERC) certified enclosure, then the standard Type III service enclosure may be larger than shown on the Standard Plans.

A larger enclosure may be supplied if the specified transformer is less than 3 kVA. A separate enclosure should be supplied to house a transformer specified between 5 kVA to 10 kVA. A typical enclosure with an internal 5 kVA to 10 kVA step-down transformer is 5 ft x 2.5 ft x 1.5 ft. Service wiring diagrams not shown on the Standard Plan shall be shown on the electrical plans and shall meet the requirements of the service utility. The name of the utility must appear on the plans adjacent to the service point.

The service equipment enclosure should be co-located 10 ft from the controller cabinet on a common PCC pad, unless directed otherwise by the Electrical Design Branch Chief.

For any service or load conductors, the designer must size the bare copper ground accordingly. Refer to Article 250-122 of NEC 2002.

Transformers shall be provided with main primary and main secondary over-current protection circuit breakers, except as listed in the Article 240.4(F) of NEC 2002. Single phase, 2-wire and 3-phase 3-wire Δ-Δ connected transformer secondary are considered to be protected by the primary over-current device as per Article 240.4(F) of NEC, provided this protection is in accordance with Article 450.3 of NEC and does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary to primary transformer voltage ratio. Additional branch circuit breakers shall be provided for each circuit connected to the transformer’s main secondary over-current protection circuit breaker. Special purpose transformers less than 1 kVA and connected to a single load, will be exempted.

Arrangements shall be made with a service utility to establish or provide service points for the installations during the design stage or when the preliminary plans are completed. It is recommended to field review the proposed service point locations with a utility representative. Three sets of plans (minimum) with proposed service points indicated shall be sent to the utility for approval.

Upon approval of service and completion of the design plans, the designer will send the “Service Request Letter”, along with the summary load and data sheets for each new or modified service, asking the service utility company to turn-on the facilities when requested by the Engineer. All of the above correspondence will be included in the RE pending file and a copy shall be provided to the District Electrical Utility Coordinator (DEUC). See Appendix O for the process flowchart.

Where another agency wants to install non-State maintained equipment (such as a separate cabinet with sampling detectors) on a State-maintained system, the equipment should have separate service.

2.12 LED SIGNAL INDICATIONS

All signal indications shall have Light Emitting Diodes (LED) modules for optical components, instead of the incandescent light bulb.

The LED signals system (vehicle and pedestrian) shall have a Battery Backup System (BBS) to provide reliable emergency power in the event of power failure or interruption. The BBS includes, but is not limited to the following:

- inverter/charger
- power transfer relay
- batteries
- a separate manually operated non-electronic bypass switch
- all necessary hardware and interconnect wiring

See Appendix I for the State furnished materials list.

For a signal installation at higher elevations and areas subjected to cold or snow weather conditions, signal heads should use tunnel type visors to prevent snow accumulation inside the signal heads. Refer to ES-4C of Standard Plans.

Tunnel type visors should also be considered for traffic signal indications at high speed approaches to prevent bird nesting inside the signal heads. Use of left or right angle visors for signal indications should be reviewed and approved by HQ Structures Special Design Branch, as it may increase wind loading effect on the signal arm.

2.13 VEHICLE SIGNAL FACES

All vehicle signal faces should have backplates.

All State, side-mounted Signal heads for Vehicle (SV) and side-mounted Signals heads for Pedestrians (SP) mounted heads should have terminal compartments (SV-1-T, SV-2-T, SP-2-T, etc.)

The designer shall revamp the signing when an existing left turn signal face with green arrow, circular yellow and red lenses is to be replaced with an all arrow signal face.

Normally, mastarm left turn signal faces should be located as close as practicable to the following:

1. One face in line with the center of a one lane left turn approach. See Placement – 3.

2. One face in line with the stripe between the 2 lanes of a 2-lane left turn approach. See Placement – 5.

Normally, mastarm signal faces for through lanes should be located as close as practicable to the following:

1. One face in line with the lane stripe between the 2 through lanes for a 2-lane approach. See Placement – 1.

2. One face in line with the center of the #2 through lane for a 3-lane approach without protected left turn. See Placement – 2.

3. One face in line with the lane stripe between the #1 and #2 through lanes for a 3-lane approach with protected left turn phase and a separate left turn lane. See Placement – 3.

4. Two faces, one in line with the stripe between lanes #1 and #2, the second in line with the lane stripe between lanes #3 and #4 for a 4-lane approach. See Placement – 9.

For mastarm signal face placements not described above, see drawings of mastarm signal face placement 1 through 11.

Mastarm mounted signal faces shall be at least 65 ft from the limit line.

All mastarm mounted signal faces and all signal faces located more than 120 ft from the limit line shall be 12” sections.

At least 2 signal faces shall be provided on each approach for each signal phase and shall be installed in accordance with California MUTCD requirement. Refer to California MUTCD, Section 4D.15, Fig. 4D-2.

A near side signal face should be provided for through traffic when the intersection exceeds 120 ft between limit lines, especially within foggy areas. The designer shall include a signal case loading higher than the load initially required, to permit future additions.

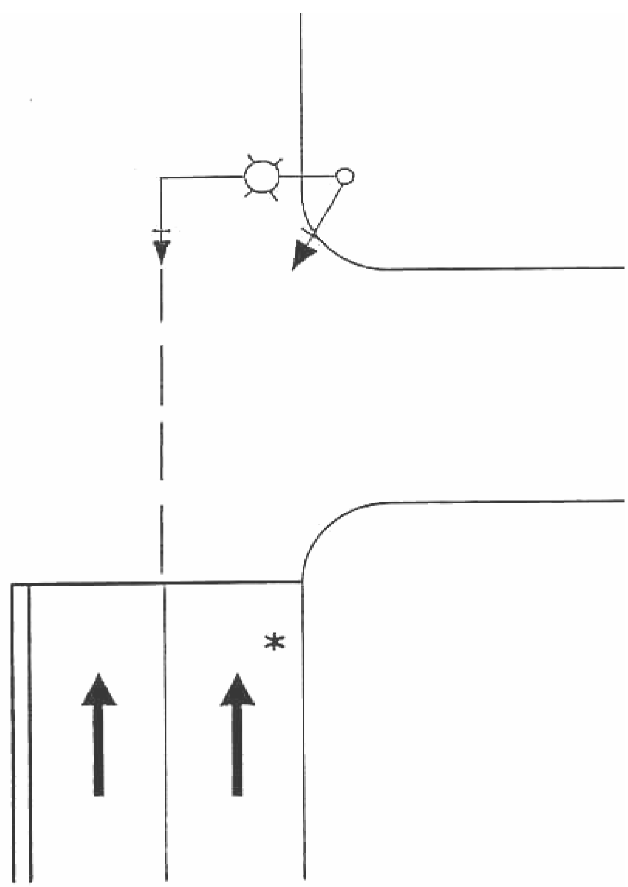
2 THROUGH LANES

3-SECTION 12" CIRCULAR MASTARM MOUNTED SIGNAL INDICATION

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 1

2 THROUGH LANES WITH PERMISSIVE LEFT-TURN ONLY AND A SEPARATED LEFT-TURN LANE

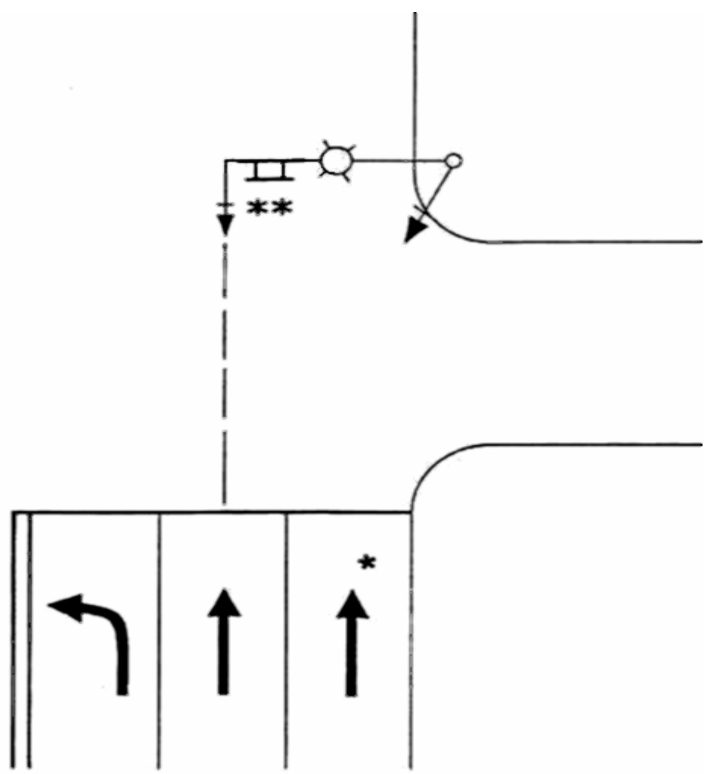
3-SECTION 12" CIRCULAR MASTARM MOUNTED SIGNAL INDICATION

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

** Install R73-7 sign when recommended by District Signing and Striping Section.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 2

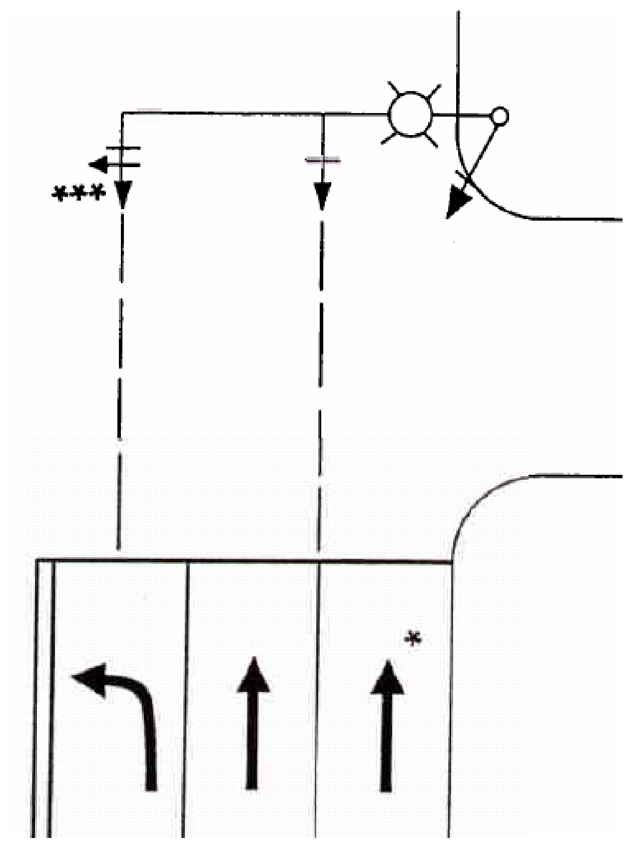
2 THROUGH LANES WITH PROTECTED LEFT-TURN PHASE AND A SEPARATED LEFT-TURN LANE

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

*** Left turn head should be as shown or a maximum 5 ft to the left from the center of the left-turn lane, unless otherwise prevented by field conditions such as above ground obstructions or underground utilities.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 3

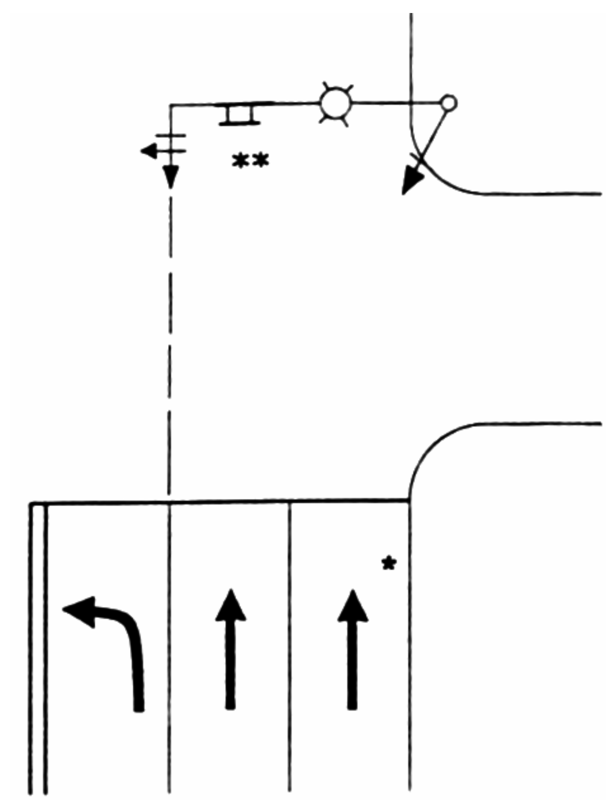
PROTECTED PERMISSIVE LEFT-TURN
OR
PERMISSIVE PROTECTED LEFT-TURN WITH MASTARM MOUNTED SIGNAL INDICATION (MAS-5A)

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

** Install R73-7 sign when recommended by District Signing and Striping Section.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 4

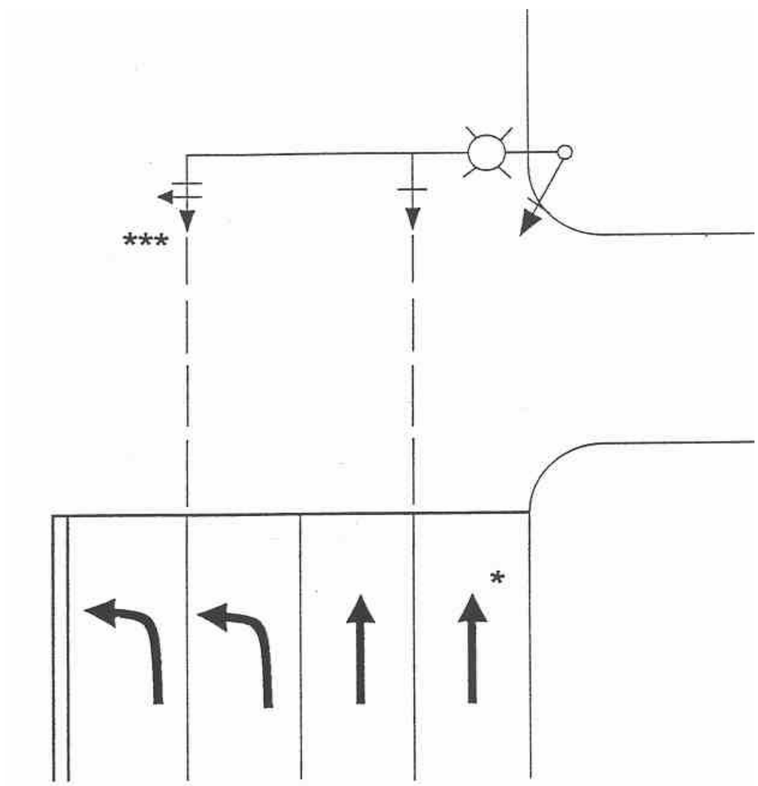
2 THROUGH LANES WITH PROTECTED LEFT-TURN PHASE AND 2 LEFT-TURN LANES

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

*** Left turn head should be as shown or a maximum 5 ft to the left from the lane line between the 2 left-turn lanes, unless otherwise prevented by field conditions such as above ground obstructions or underground utilities.



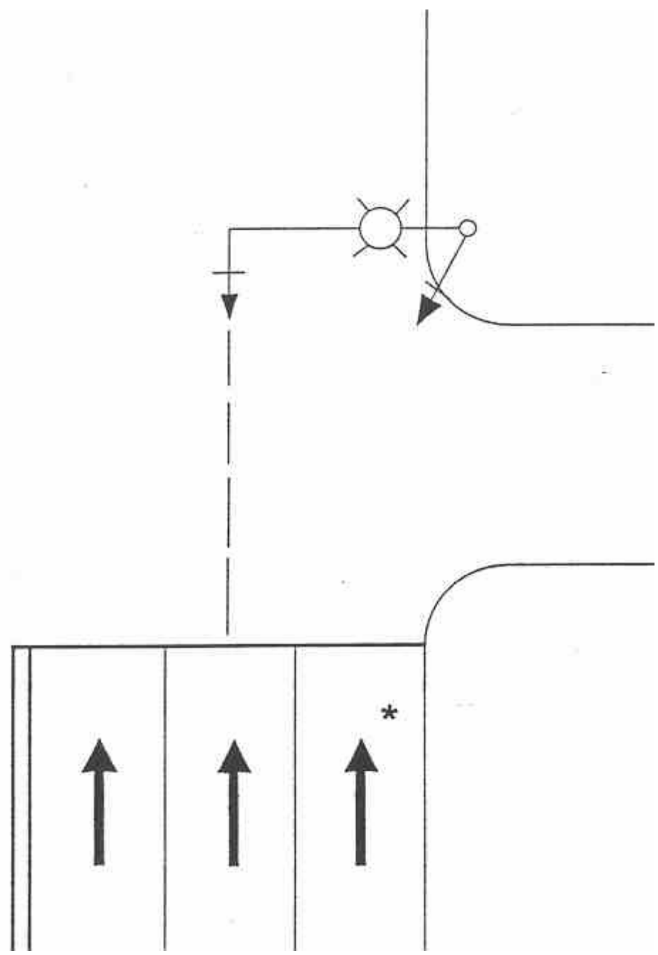
CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 5

3 THROUGH LANES ONLY

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 6

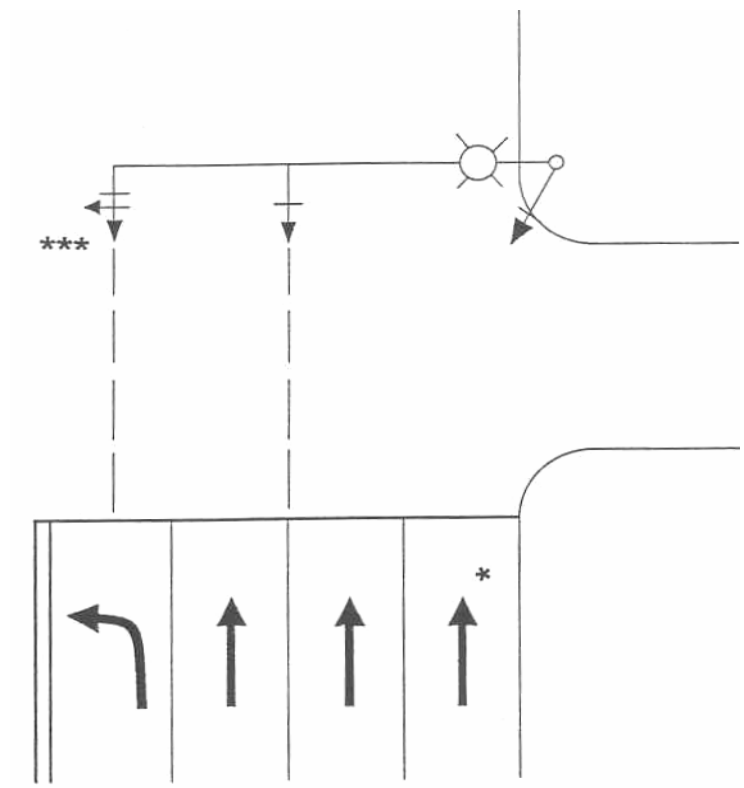
3 THROUGH LANES WITH PROTECTED LEFT-TURN PHASE AND A SEPARATE LEFT-TURN LANE

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

*** Left turn head should be as shown or a maximum 5 ft to the left from the center of the left turn lane, unless otherwise prevented by field conditions such as above ground obstructions or underground utilities.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 7

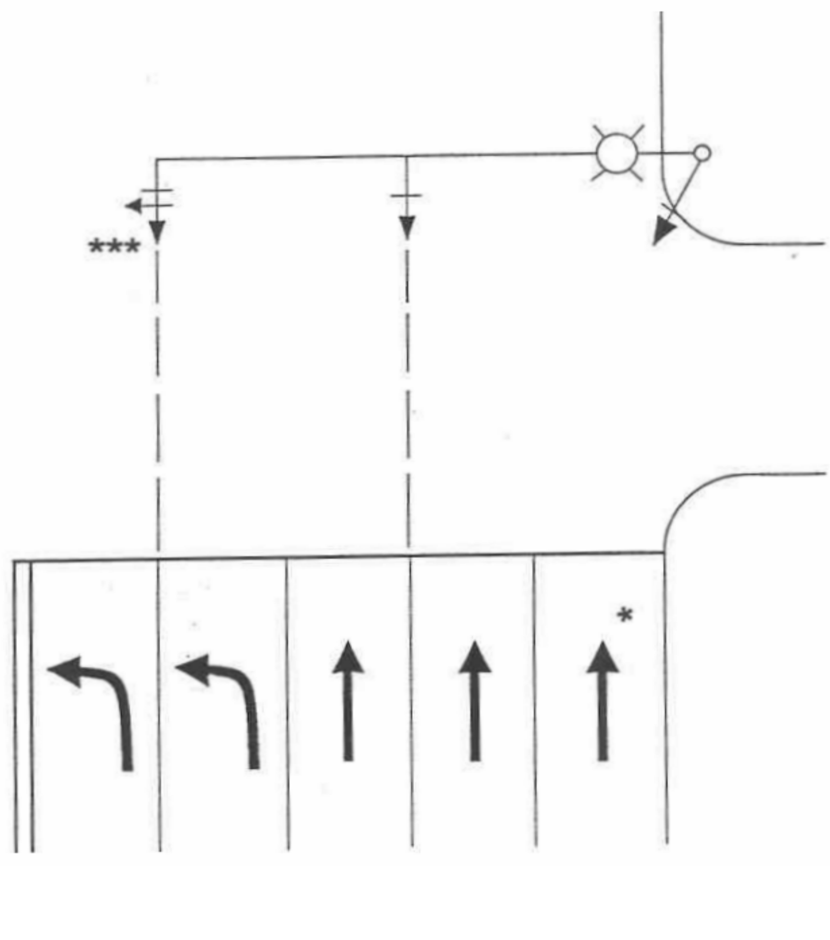
3 THROUGH LANES WITH PROTECTED LEFT-TURN PHASE AND 2 LEFT-TURN LANES

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

*** Left turn head should be as shown or a maximum 5 ft to the left from the lane line between the 2 left-turn lanes, unless otherwise prevented by field conditions such as above ground obstructions or underground utilities.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 8

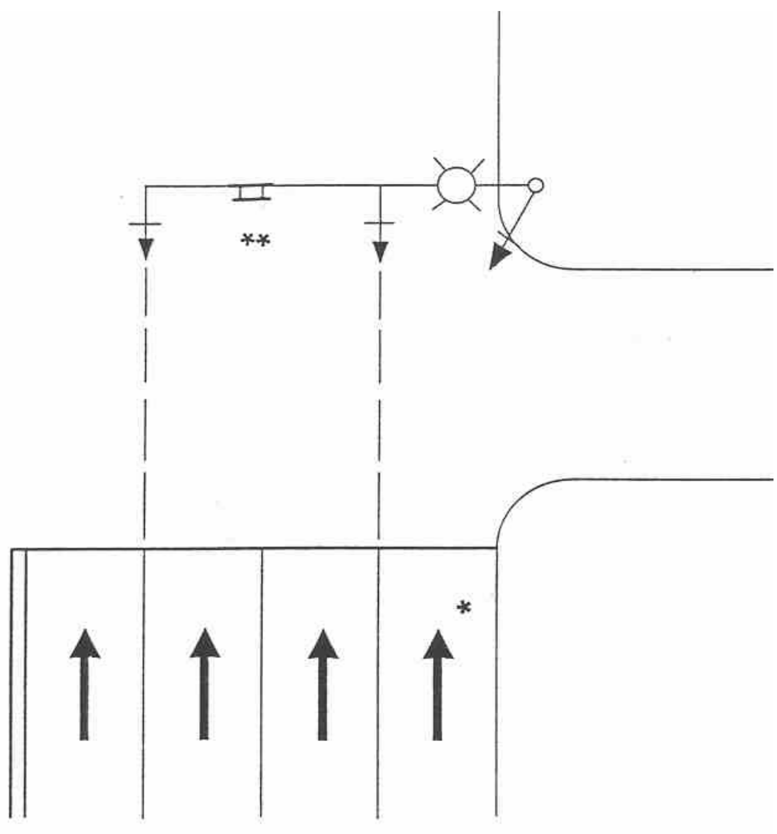
4 THROUGH LANES ONLY

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

** Install R73-7 sign when recommended by District Signing and Striping Section.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 9

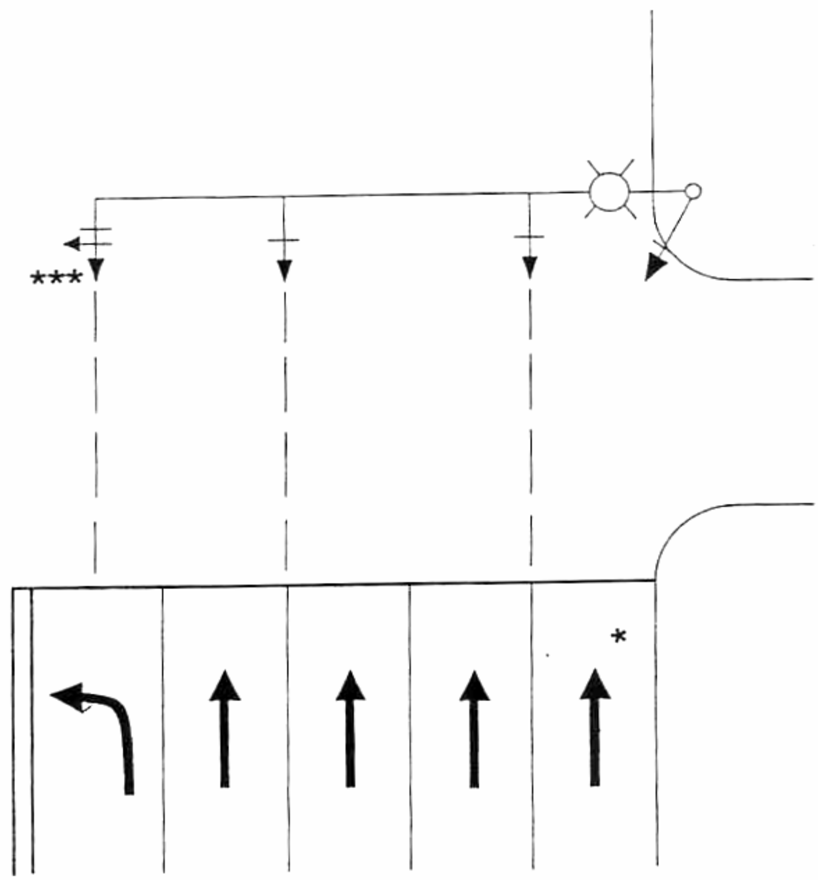
4 THROUGH LANES WITH PROTECTED LEFT-TURN PHASE AND A SEPARATE LEFT-TURN LANE

NOTES:

LEGEND
— — Preferred Placement

* Optional lane with a through and right turn lane.

*** Left turn head should be as shown or a maximum 5 ft to the left from the center of the left turn lane, unless otherwise prevented by field conditions such as above ground obstructions or underground utilities.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 10

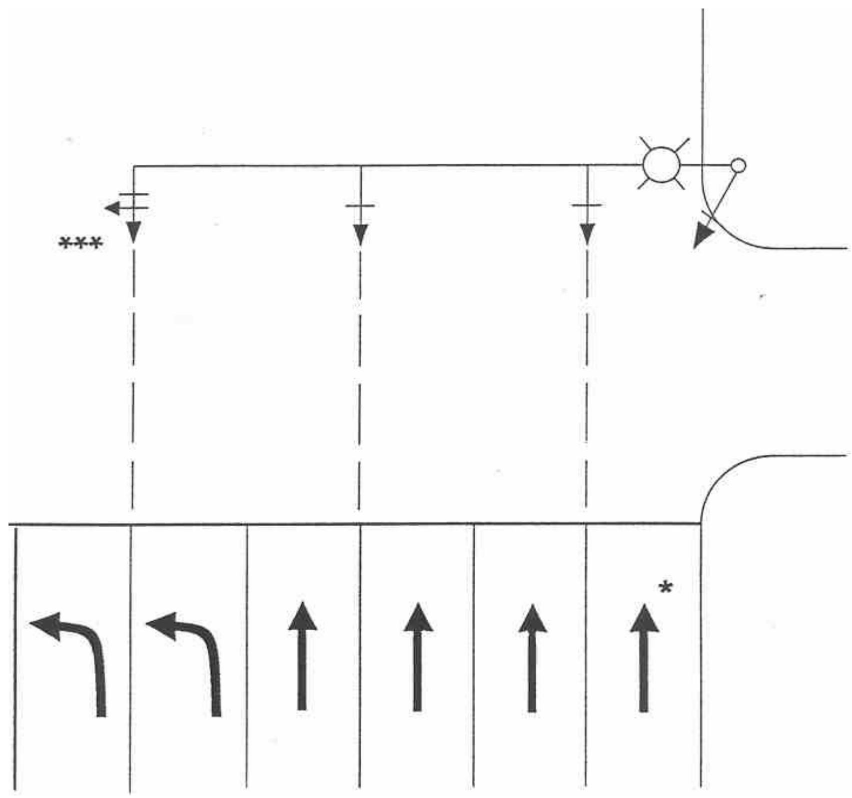
4 THROUGH LANES WITH PROTECTED LEFT-TURN PHASE AND 2 LEFT-TURN LANES

NOTES:

LEGEND
— — — Preferred Placement

* Optional lane with a through and right turn lane.

*** Left turn head should be as shown or a maximum 5 ft to the left from the lane line between the 2 left-turn lanes, unless otherwise prevented by field conditions such as above ground obstructions or underground utilities.



CALTRANS MASTARM SIGNAL FACES
PLACEMENT – 11

2.14 PEDESTRIAN SIGNAL HEADS

Type A pedestrian signal heads shall be used.

Pedestrian signal heads should be located where there is minimum visibility interference from vehicles stopped at the crosswalk or limit line.

2.15 PHASE DIAGRAM

A phase diagram shall be provided for each signal plan (see typical plans). All the phases including the overlaps should be properly designated.

2.16 CONDUCTOR AND CONDUIT SCHEDULE

A conductor and conduit schedule shall be provided, preferably on the same sheet as the signal plan. For Conductor and Conduit Schedule, see Sheet E-2.

2.17 POLE AND EQUIPMENT SCHEDULE

A pole and equipment schedule shall be provided. It should be on the same sheet as the conductor and conduit schedule. For Pole and Equipment Schedule, see Sheet E-2.

2.18 SIGNAL INTERCONNECT

Signals less than 0.5 mile apart should be considered for signals interconnect.

The designer should consider master/slave locations. Telephone, fiber optics or wireless communications should be provided at the master location and at isolated intersections.

2.19 RAILROAD PREEMPTION

Preemption is to clear any stopped traffic on the railroad track before the arrival of train near signalized intersection. To provide preemption, the traffic signals need to be interconnected with railroad signals.

A No. 5 pull box should be installed within the roadway right-of-way as close to the train control box as practical. Two No. 14 AWG conductors should be provided in a 1" (minimum) conduit run (when separate conduit is necessary) between the pull box and the controller cabinet. Arrangements shall be made with the railroad authority to provide contact closure input by installing a conduit with two conductors from the train control box to the State pull box. The cost for such installation should be shown in the preliminary estimate under "State Furnished Materials and Expense."

2.19.1 SIGNALIZED INTERSECTION NEAR RAILROAD TRACKS

Where a signalized highway intersection exists in close proximity to a railroad track crossing, the railroad warning devices (such as flashing-lights) and the traffic signal control equipment should be interconnected. The normal operation of the traffic signals controlling the intersection should be preempted to operate in a special control mode when a train is approaching. Preemption is provided to the signalized intersection so that any queued traffic on the railroad tracks is cleared before the arrival of a train.

The design engineer needs to be aware of the following guidelines recommended by National Transportation Safety Board (NTSB) and California Public Utilities Commission (CPUC):

- "Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices", Institute of Transportation Engineers (ITE), Committee TENC-4M-35
- "Traffic Signal Operations Near Highway-Rail Grade Crossings", National Cooperative Highway Research Program (NCHRP), synthesis 271
- "Guidance On Traffic Control Devices At Highway-Rail Grade Crossing", US Department of Transportation, Highway/Rail Grade Crossing Technical Working Group (TWG)
- "Design Guidelines For At-Grade Intersections Near Highway-Railroad Grade Crossings", Texas Transportation Institute (TTI)

2.19.1.1 DESIGN CONSIDERATION

When the rail road track crossing is equipped with a flashing-light system and is located within 200 ft of an intersection controlled by a traffic control signal, the traffic control signal should be provided with preemption capability. Refer to California MUTCD, Sections 4D.13 and 8D.07. The following should be considered and be included when planning or designing.

- Railroad preemption should be based on a detailed queuing analysis such as below, rather than just using the criteria of the pre-specified distance of 200 ft:

    a) roadway approach traffic volumes
    b) number of traffic lanes and lanes layout
    c) nearby traffic signal timing
    d) saturation flow rates
    e) motor vehicle arrival characteristics
    f) motor vehicle size and classification
    g) the frequency of train movements
    h) type of trains (whether passenger or freight)

- The distance between the railroad track crossing and signalized highway intersection must be carefully evaluated. Traffic and geometric conditions must be reviewed and analyzed.
- For the shorter distances (about 65 ft) where the clear storage distance between the railroad track and the highway intersection limit line is not sufficient to safely store a truck or vehicles that regularly queue across the tracks, a **PRE-SIGNAL** should be considered.
- The designer should verify that the railroad 'Preemption Sensor Card' is furnished as part of the controller assembly and that the traffic signal controller unit operation is compatible with the railroad controller cabinet.
- The designer should verify that the traffic signal controller provides basic preemption sequencing including entry into preemption, termination of the interval in operation, clearing track intervals (including clear track green), preemption hold intervals, and return to normal operations.
- The designer should verify the traffic signal controller's re-serviceability to accept and respond to a second demand for preemption, immediately after a first demand for preemption has been released, even if the first programmed sequence is not complete. In other words, the controller must return to the start of a full track clearance green interval with a second preemption demand.

2.19.1.2 DESIGN TIME ELEMENT FOR PREEMPTION

The California MUTCD specifies a 20 seconds minimum time for the railroad circuit to activate warning devices, prior to train arrival at the railroad track crossing. The following should be considered when designing time element for a **Preemption** operation:

- approach speed of train and of vehicles on all approaches to the highway and railroad track crossing
- intersection and crossing geometry (including crossing angle, length of crossing, track clearance distance, intersection width, distance between intersection and crossing, approach tracks and close proximity of parallel streets)
- for highway rail track crossings located adjacent to a signalized intersection, the traffic signal system may require additional time to terminate phases and clear any queued motor vehicles off the tracks
- vehicle queue lengths and dissipation rates between the intersection limit line and the railroad track
- special class vehicle such as buses, large trucks or trucks carrying hazardous materials (HAZMAT)
- traffic signal timing and long clearance intervals (yellow/red) for high speed approaches
- any pedestrian walk or clearance interval(s) in effect when the preemption is initiated, shall immediately be terminated and all pedestrian signal faces shall display the steady DON'T WALK or upraised HAND
- types of active warning (presence or absence of warning gates, flashing-light signs alone, flashing-light signals with approach side railroad gates only or with four–quadrant gates)
- To properly design the highway rail preemption system, both the railroad authority and the highway agency should understand how each system operates. An engineering study should be conducted at the interconnected location to determine the minimum preemption warning time necessary to adequately clear traffic from the crossing, in the event of an approaching train.

2.19.1.3 WARNING TIME

If one item or a combination of the above items requires warning time more than the normal 25 seconds, the following techniques may be considered:

- Uniformly extend the railroad circuit warning time for both the railroad and traffic signal controller units, providing simultaneous preemption.
- Use advance preemption to start the highway traffic signal preemption sequences before the railroad-warning devices are activated at the railroad crossing.

2.19.1.4 PRE-SIGNALS

Pre-signals are operated as part of the highway intersection traffic signal system. Their displays are integrated into the railroad preemption program. An engineering study should be made to evaluate the various elements involved in a pre-signal.

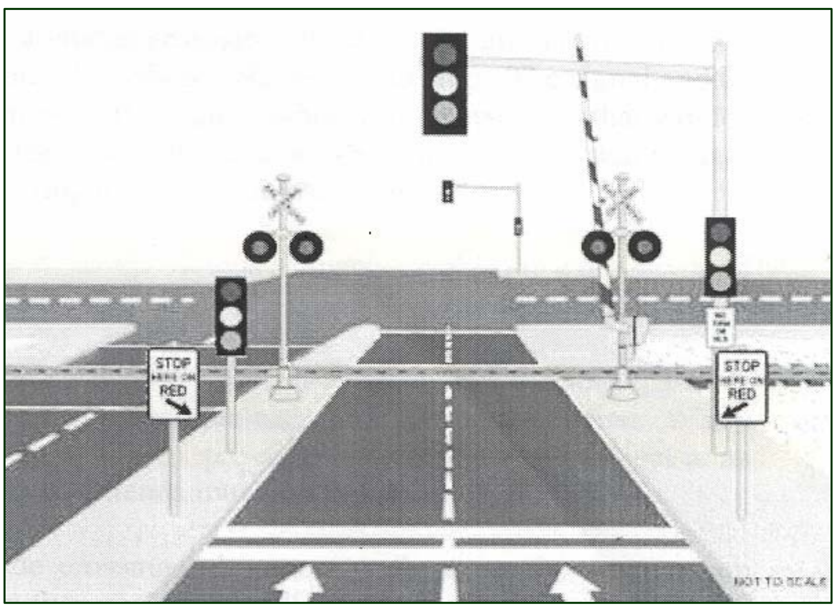


Figure 4. Pre-signal Location at Automatic Gate Crossing

Some of the considerations are below:

- Where the highway intersection is less than 50 ft from the highway rail crossing (75 ft for a roadway regularly used by multi-unit vehicles) of a signalized intersection, pre-signals should be considered.
- Where the clear storage distance is greater than 75 ft, pre-signals could be used, subject to an engineering study.

- Where geometric considerations in advance of the crossing complicate the installation of a pre-signal on a separate support in front of the railroad signal, the placement of railroad flashing-light signals and traffic signals on the same support should be considered. This may reduce visual clutter at the pre-signals and increase driver visibility. A written agreement between the highway agency and railroad authority may be required.
- Pre-signals may also be beneficial if railroad gates are not provided. This pre-signal is a supplemental traffic signal that should be carefully designed to avoid trapping vehicles on the tracks. The pre-signals are connected in the same phase as that of the controlled traffic at the railroad approach (timing offset may be needed).
- Horizontal distance limiting signal indications for the far side mastarm signal should be required to reduce driver confusion between the pre-signal and the far side mastarm signal.

2.19.1.5 OTHER DESIGN FACTORS

- The designer must ensure that placement of highway traffic signals do not block the view of railroad flashing-light signals.
- Installation of roadway lighting at railroad track may be considered to potentially reduce the level of hazard.
- Consideration should be given to include or request supplemental median treatments to discourage drivers from attempting to circumvent the gates.
- When four-quadrant railroad gates are used, it is critical to prevent trapping vehicles on the tracks.
- When the train speed is always slow (less than 10 mph), highway traffic signals may be used instead of flashing-light signals. (California MUTCD, Section 8D-07). Always check with the Public Utilities Commission's General Order for a specific location and approval.
- When the railroad crossing is located between two closely spaced signalized intersections, the two highway traffic signals shall be interconnected and should be preempted synchronously to permit the track to be cleared in both directions.
- When multiple tracks or tracks of different railroads cross a highway within preemption distance of the signalized intersection, all tracks should be considered as a single crossing and the clear track green interval should be of sufficient length to allow a queue to clear across all the tracks. When more than one railroad is involved, all of the railroads owners should participate in the design.
- Provide battery backup power for preemption traffic signals installations.

2.19.1.6 SIGNING AND STRIPING

- The designer must verify that the design plan includes railroad advance warning signs (W10-1) in advance of every highway rail track crossing. For advance warning signs, refer to California MUTCD, Section 8B.04.
- An emergency phone number should be posted at the crossing. This posting should include the USDOT highway rail track crossing identification number, highway or street name or number, railroad milepost and other pertinent information.
- Where the roadway approaches to the crossing are paved, pavement markings are to be installed as described in the California MUTCD, subject to engineering evaluation.
- Signs such as ‘STOP HERE ON RED’ and ‘DO NOT STOP ON TRACKS’ of California MUTCD (Sections 8B.07 and 8B.11) may also be used.
- When there is not enough storage space between the signal and the railroad track, signs prohibiting right turns on red may be used during preemption.
- All highway rail track crossings should be equipped with approved passive devices. Passive traffic control devices are those not activated by trains, including pavement markings and signs. Sign such as ‘Storage Space’ and plaque such as ‘Advisory Speed’ should also be considered except as specified by the California MUTCD.

2.19.1.7 MOTOR VEHICLE DRIVER NEEDS ON THE APPROACH

Some essential elements required for safe passage through the railroad crossings:

- *Advance Notice*: ability to see a train and/or the traffic control device(s) at the railroad crossing ahead sufficiently in advance so a driver can bring the vehicle to controlled stop at least 15 ft short of the nearest railroad track.
- *Clearing Sight Distance*: a driver stopped 15 ft short of the nearest rail must be able to see far enough down the track in both directions to determine if sufficient time exists for moving their vehicle safely across the tracks to a point 15 ft past the farthest rail, prior to the arrival of a train.
- *Minimum Clearance Sight Distance* for various train speeds and vehicle types: See table below for computed distance.
- Stopping and corner sight distance deficiencies may be treated immediately with warning or regulatory traffic control signs, such as a STOP sign, with appropriate advance warning signs. For interim measures, temporarily close the crossing or restrict the use of the roadway by the class of track.

Table 5. Clearing Sight Distance, ft *

Train Speed mph	Car	Single Unit-Truck	Bus	Semi-Truck	65-ft Double Truck	Pedestrian **
10	105	185	200	225	240	180
20	205	365	400	450	485	355
25	255	455	500	560	605	440
30	310	550	600	675	725	530
40	410	730	795	895	965	705
50	515	910	995	1120	1205	880
60	615	1095	1195	1345	1445	1060
70	715	1275	1395	1570	1680	1235
80	820	1460	1590	1790	1925	1410
90	920	1640	1790	2015	2165	1585

* A single track, 90-degree level crossing.

** Walking 3.5 fps across 2 sets of tracks feet apart, with a two second reaction time to reach a decision point 10 ft before the center of the first track, and clearing 10 ft beyond the center line of the second track. Two tracks may be more common in commuter station areas with pedestrians.

2.19.1.8 PEDESTRIAN AND BICYCLISTS CONSIDERATION

- Non-motorist crossing safety should be considered at all highway rail track crossings, particularly at or near commuter stations and at non-motorist facilities, such as bicycle/walking trails, and pedestrian only facilities.
- Passive and active devices may be used to supplement highway related active control devices to improve safety at highway rail crossings. Passive devices include fencing, swing gates, pedestrian barriers, pavement markings, texturing, refuge area and fixed message signs. Active devices include flashers, audible active control devices, automated pedestrian gates, pedestrian signal, variable message signs, and blank out signs.
- Passive and active devices should be considered at crossings with high pedestrian traffic volumes, high train speeds or frequency, extremely wide crossings, complex highway rail track crossing geometry with complex right of way assignment, school zones, inadequate sight distance, and/or multiple tracks.
- The above devices should be designed to avoid trapping pedestrians between sets of tracks. Refer to the California MUTCD, Section 10D.08.
- Consideration should be given to clearances for movement of the counter weight arm portion of the gate drive unit in a median and adjacent to sidewalk locations with pedestrians and Americans with Disabilities Act (ADA) requirements.

2.20 PEDESTRIAN BARRICADES

Where pedestrians are not allowed to cross certain legs of the intersection and a significant number of pedestrians use the intersection, a pedestrian barricade may be installed in addition to the R96, “NO PED XING”, sign.

2.21 FLASHING BEACONS

Flashing Beacons (FB) using, W3-3 or W3-3a “SIGNAL AHEAD” sign should be located as directed by the Electrical Design Branch Chief or the Division of Signing and Striping.

2.22 LIGHTING

All traffic signals should use 240 V(ac) lighting systems whenever possible.

2.23 STATE FURNISHED MATERIALS

Toward the completion of the design, the designer shall fill out the State Furnished Material form and send to the Maintenance supervisor for their records. A copy of the cost document should be sent to the District warehouse to coordinate ordering the equipment.

The designer should refer to the latest department policy for state-furnished material for the Model 170/2070 controller assembly, cabinet, Changeable Message Signs (CMS) system, and Battery Backup System (BBS). For a list of State furnished materials, see Appendix I.

3.0 LIGHTING AND SIGN ILLUMINATION

For typical lighting and sign illumination, see Sheet E-3.

Lighting should be designed for at least 125% of the foot-candle value required, to allow for Luminaire Dirt Depreciation (LDD) and Lamp Lumen Depreciation (LLD). Refer to the Highway Design Manual or Department policy.

Conduit, pull boxes and foundations for future lighting should be considered during new bridge structure design.

Lighting circuit diagrams should be on project plans.

3.1 STANDARDS

Where a slip base is required, the project plans should specify a “slip base” standard: type 30 or 31. New Type 15 standards requiring slip bases should be designated ’15-SB’. Standards installed within clear recovery zone shall be protected, moved, made to yield or shielding, complying with HDM chapter 300, topic 309 clearance.

For the use of slip base under lighting standards, refer to the “Breakaway/Slip Base Under Electroliers Located Along Freeways, Expressways and Conventional Highways” policy memorandum dated October 30, 1987 (See Appendix B.)

The fiberglass lighting pole, Shakespeare models (AHW27 through AHW35 series) are approved and acceptable alternatives to slip base pole. The designer shall consult the Electrical Design Branch Chief regarding the use of fiberglass poles.

The designer shall consult the District Utility Coordinator (DUC) regarding the numbering of standards.

3.2 SIGN LIGHTING FIXTURES

Provisions for future lighting shall be installed for any overhead sign, which will not immediately be illuminated at the time of its installation.

The designer shall consult the Electrical Design Branch Chief or Division of Signing and Striping regarding the need for illumination of non-action or lightweight signs. When illumination for lightweight signs that are less than 5 ft wide is needed, 3 ft fluorescent sign fixtures may be used.

Unless directed otherwise by the Electrical Design Branch Chief, when a circuit serving an existing overhead action sign is modified, the florescent sign lighting fixtures should be replaced with the updated sign lighting fixtures.

Refer to Section 2 of the California MUTCD.

3.3 FREEWAY INTERCHANGE LANES

Freeway interchange lanes are the acceleration lane (entrance-ramp), deceleration lanes (exit-ramp) or any extra lane(s) that starts from an entrance-ramp and ends at the next exit-ramp. Lighting may be considered based on a variety of factors including:

- mainline traffic volume
- ramp traffic volume
- weaving activities
- short weaving distance
- the amount of vertical or horizontal fixed objects adjacent to the interchange lane
- background ambient lighting
- non-standard shoulder width
- other geometric reasons.

Lighting for freeway interchange lanes should be considered to illuminate the full length of the lane if it is shorter than ½ mile. All electroliers should be spaced uniformly when possible. Typically, 310 W electroliers are spaced 180 ft apart while 200 W electrolier are 150 ft apart. Additional lighting may be installed based upon the unique requirements.

3.3.1 ENTRANCE RAMP

A minimum of one luminaire should be placed at each freeway entrance ramp. Typically, a 310 W electrolier is placed at the acceleration lane (at 9 ft wide point before lane decays) and optional lighting 180 ft upstream. Refer to the Highway Design Manual.

However, for a very short entrance-ramp where the traffic is expected to merge sooner, the electrolier may be placed at the gore point.

Additional electrolier(s) can be placed at 180 ft apart ‘downstream’, for the entrance-ramp weaving traffic. The placement of electrolier(s) may also be based on the conflicting points of the weaving area of traffic (this may require observation of weaving/merging pattern).

3.3.2 EXIT RAMP

A minimum of two luminaire should be placed at each freeway exit-ramp. Typically, the first electrolier (310 W) is placed where the deceleration lane is a full 12 ft wide (the gore point), while the subsequent electrolier(s) is placed 180 ft apart downstream. However, more electrolier(s) can be placed ‘upstream’ before the gore point, if traffic warrants.

It is important to avoid conflict with the G24 overhead sign placed at the approach of the exit ramp.

3.4 PHOTOELECTRIC CONTROL

Separate circuits should not be used for highway lighting and sign illumination.

Use Type V photo electric controls, except in high snow areas where the Photoelectric Unit (PEU) may need to be placed on a standard.

4.0 ELECTRICAL FAULT PROTECTION

The designer is responsible for designing safe circuitry that delivers power from the supplying utility to a given load safely, economically and at its rated voltage. For safety reasons the electrical equipment and associated circuitry should be designed as to facilitate:

- the operation of over-current devices to protect equipment
- limiting the voltage to ground during a fault for personnel safety

Limiting the voltage to ground also facilitates operation of the over-current protective devices.

All equipment in an installation, including protective devices, must be able to interrupt safely any limited fault currents that may be present. When designing be sure to consider:

- All equipment must have the capacity to operate safely at the prospective fault current.
- If fault current limiters are to be used, they must be selected to prevent fault condition from exceeding a predetermined level (e.g. the maximum rating of equipment used in that part of the installation) and installed to comply with the required standard.

4.1 TYPES OF FAULT

Most common types of electrical faults are:

- line to line fault
- line to ground fault
- arcing fault to ground

The arcing fault to ground is the worst type of fault that can occur on an electrical circuit. There is a substantial voltage drop across the arc during arcing and that results in less voltage available for driving the fault current in the circuit for the timely operation of the over-current protective devices. Therefore, the designer must pay close attention during design so that the resultant circuitry for supplying a given load must perform in a predictable manner to protect personnel and equipment during adverse conditions.

4.2 FAULT CURRENT PATH

The fault current path shall be permanent, electrically continuous, capable of safely carrying the maximum fault likely to be imposed on it and shall have sufficiently low impedance to facilitate the operation of the over-current protective device under fault conditions. Electrical equipment, wiring or other electrical conductive material likely to get energized shall be installed in a manner that creates a permanent, low-impedance circuit from any point on the wiring system to the electrical supply source. The EARTH shall not be used as the sole equipment grounding conductor or for fault current path. For more details refer to Article 250-2(d) of California Electrical Code (CEC) and Article 250 “Grounding” of the NEC.

4.3 CIRCUIT LENGTHS

Lighting circuits with shorter lengths are generally fine when utilizing 8 AWG. However, circuits with longer lengths require close attention to all of the circuit parameters such as circuit length, wire size, circuit load, branch circuit breaker trip rating and supply voltage.

Normally a voltage drop for a given circuit load can be satisfied without substantial increase in the wire size. See “Voltage Drop Calculation” in Section 2 of this Design Guide. However, to satisfy the performance of the fault current path, it can become very uneconomical when the wire size has to be increased for a long run. In this situation, the designer needs to look at alternatives such as:

- lowering breaker trip rating (e.g. lower from 30A to 15A breaker)
- utilizing ground fault interrupter devices
- changing a given voltage level to a higher permissible voltage level (since transformers are inexpensive, circuits with longer than usual lengths should be stepped up to 480 volts)

4.4 ENERGY GENERATED DURING FAULT

The energy generated during any kind of fault shall not be more than:

- 4,000 kW-cycles for above ground faults
- 10,000 kW-cycles for underground faults

When this limit is used, all luminaire fuses shall be installed inside the pull box and not inside the pole.

The high levels of energy dissipated during faults involving high currents can cause extensive damage and could lead to injury or death for anyone working nearby. The following conclusions were made by experiments in the past to estimate the resultant damage from the fault energy.

Table 7. Damage from Fault Energy*

Fault Energy	Damage Severity
100 kW-cycles	Location of fault identifiable from spit marks on metal and from smoke marks.
2,000 kW-cycles	Minor damage; probably no damage to hardware, equipment usually can be restored to service by cleaning smoke marks and repairing insulation.
10,000 kW-cycles	Serious Damage but usually contained within 12 gauge metal enclosure.
20,000 kW-cycles	Severe Damage. Fault probably will burn through metal enclosure and spread to other sections of the equipment.
Over 20,000 kW-cycles	Considerable destruction of equipment and fire, in proportion to the amount of fault energy.

* EC&M magazine

4.5 SHORT CIRCUIT ANALYSIS

The energy generated during ground fault can be calculated in kW-cycles:

$$\text{kW} - \text{cycles} = \frac{I_f \cdot V_{arc} \cdot t_{sec} \cdot 60\,\text{cycles/sec}}{1000}$$

Where, t_{sec} = maximum tripping time in seconds for the circuit breaker

V_{arc} = voltage across fault arc
= 50 volts, empirically for a 120 V system

Fault current, $I_f = \dfrac{V_{effective}}{Z_{effective}}$

$V_{effective}$ = effective voltage producing fault current
= $V_{available} - V_{arc}$, e.g. 115 V – 50 V

$Z_{effective}$ = effective impedance (See Section 2.3.2)
$Z_{effective/1000'} = (R\cdot\cos\theta + X\cdot\sin\theta)$

For total circuit length, $Z_{effective/1000'} = 2\,(R\cdot\cos\theta + X\cdot\sin\theta)\cdot$ for single-phase
$Z_{effective/1000'} = \sqrt{3}\,(R\cdot\cos\theta + X\cdot\sin\theta)\cdot$ for 3-phase

For the values of R and X, refer to chapter 9, table 9 of NEC.

m = Multiples of circuit breaker rated current

EXAMPLE: Calculate Ground Fault Energy for the following circuit parameters: uncoated copper wire in PVC conduit, single phase, circuit breaker rating of 15-25, see circuit breaker curve in the appendix K.

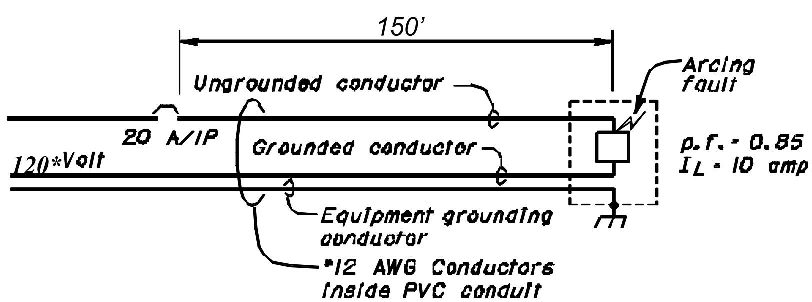


Figure 5. Circuit Diagram

* 120 Volts at service equipment and 115 volts at arcing fault location due to V_d.

Here, V_{arc} = 50 volts (empirically)

Then, $V_{effective} = V_{available} - V_{arc}$
$V_{effective} = 115 - 50 = 65$ volts

Power factor, $\text{Cos}\,\theta = 0.85$
$\theta = 31.79^{o}$, then $\text{Sin}\,\theta = 0.527$

Find R and X, R=2 and X=0.054, for 1000' per NEC

Impedance, $Z_{effective/1000} = (R \cdot \text{Cos}\theta + X \cdot \text{Sin}\theta)$

$$Z_{effective\,/\,1000'} = (2 \cdot 0.85 + 0.054 \cdot 0.527) \quad \Rightarrow 1.728\ \Omega$$

$$Z_{effective} = 2 \times 1.728\ \Omega \times \frac{150'}{1000'} \quad \Rightarrow 0.52\,\Omega$$

Note: for 1-phase, the circuit length is multiplied by 2 to account for return path.

Fault current,

$$I_f = \frac{V_{effective}}{Z_{effective}}$$

$$I_f = \frac{65\ \text{V}}{0.52\ \Omega} \quad \Rightarrow 125\ \text{Amps}$$

Multiples of rated current,

$$m = \frac{I_f}{\text{C.B. rating}}$$

$$m = \frac{125\ \text{Amps}}{20\ \text{Amps}} = 6.25$$ (20 A, C.B. from Figure 5)

Maximum trip time, $t_{sec} \approx 5$ seconds (See C.B. curve in appendix K)

Finally,

$$\text{energy} = \frac{I_f \cdot V_{arc} \cdot t_{sec} \cdot 60\,\text{cycles/sec}}{1000} \quad \text{(kW-cycle)}$$

$$\text{energy} = \frac{125 \cdot 50 \cdot 5 \cdot 60\,\text{cycles/sec}}{1000} \quad \text{(kW-cycle)}$$

energy = 1875 kW-cycles

Since 1875 kW-cycle is less than 4,000 kW-cycle for above ground installation, it is okay.

5.0 INTELLIGENT TRANSPORTATION SYSTEM / TRANPORTATION MANAGEMENT SYSTEM

For a typical Transportation Management System (TMS) design, see Sheets E-4 and E-5.

Typical Intelligent Transportation System (ITS)/TMS elements include (but are not limited to) CCTV, CMS, HAR, EMS, RWIS, Traffic Monitoring Station/Vehicle Detection Station, MVDS, and RMS. All of the ITS/TMS elements mentioned above share the following general notes:

1. See Conductors, Conduits, Pull Boxes, and Detectors under "Signal and Lighting" section.
2. The designer should consult with the District Traffic Operations, TMC Support and maintenance for exact location of ITS/TMS equipment.
3. The designer should consider installation of a vehicle maintenance pullout for all ITS/TMS elements.
4. The design engineer should ensure that funds are allocated for the installation costs associated with installing compatible communication equipment.
5. The designer should consult with District Traffic Operations, TMC Support for the following items:

   - location of the Telephone Demarcation Cabinet (TDC) and type preferences.
   - location and type of existing communication infrastructure and facilities.
   - preference for communication transport and topology alternatives. Since the districts are moving towards Internet Protocol (IP) based communication with multi-tier network topologies for data concentration and transport, the designer should be fully aware of the preferred network architecture and the data concentration points.

5.1 CLOSED CIRCUIT TELEVISION

The Closed Circuit Television (CCTV) camera system is furnished and installed by the contractor as a complete and operational system which includes the camera, camera lens, pan/tilt drive unit, environmental enclosure with sun shroud, mounting bracket, camera control receiver/driver and cables. For more information the designer should consult with the Traffic Operations, TMC Support.

5.1.1 LOCATION

The designer shall consult the District Traffic Operations, TMC Support for the camera type and exact location of the camera pole. Additionally, the camera pole must be installed outside of the Clear Recovery Zone. In a situation where this would not be possible, then the pole shall be protected by a Metal Beam Guard Railing (MBGR) or other protective measure.

5.1.2 CONTROLLER

The CCTV controller assembly is housed in a contractor-furnished housing, which could include a Power Distribution Assembly (PDA), Camera Control Unit (CCU), Video Encoder Unit (VEU), and other necessary communications equipment. The housing shall be installed per the Standard Plans, "ELECTRICAL SYTEMS (CONTROLLER CABINET DETAILS)" on a Type 334 cabinet foundation. Refer to ES-3C of Standard Plans.

A camera multi-conductor cable capable of providing power, control, and video transmission is also supplied by the Contractor, which shall run continuous from the controller cabinet to the camera without any splices.

5.1.3 POWER

The CCTV camera system shall be designed to operate on single phase, 120/240 V(ac) service with a typical load of 1200 W.

5.1.4 COMMUNICATIONS

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for video signal transmission from a roadside CCTV camera.

1. Fiber Optics or Copper infrastructure, where available
2. Digital Subscriber Line (DSL)
3. Leased Cable TV Services
4. Agency owned non-licensed Microwave Systems.
5. Evolution Data-Only (EVDO) based on service availability
6. Integrated Services Digital Network (ISDN)
7. General Packet Radio Service (GPRS) for low bandwidth encoded video snap shots
8. Twisted pair or low bandwidth leased services may be used for sending camera control signals

5.2 CHANGEABLE MESSAGE SIGN

The Standard Changeable Message Sign (CMS) systems are the Model 500/510/520 Xenon bulb or LED matrix.

- The Model 500 sign is typically installed alongside major freeways.
- The Model 510 sign, which is slightly smaller, is for use on conventional highways.
- The Model 520 may be used for 2-lane highway or under special consideration where Model 510 is not tolerable / acceptable.

All signs are State furnished as a system, which includes the CMS sign, controller cabinet, controller isolation assembly (CIA), CMS harnesses #4 (24 pairs, No. 18 AWG, multicolored pairs) and #5 (6 pairs, No. 18 AWG, multicolored pairs) and all other peripheral equipment necessary to operate the system. The support for CMS (e.g. pole) is not State furnished.

The designer shall contact the HQ CMS coordinator to place an order for the CMS sign, prior to finalizing the PS&E.

The designer should avoid installing a CMS in the median. If it must be installed in the median, then the designer should notify the HQ coordinator to accommodate the long delay time when placing this CMS order. A CMS installed in the median is especially designed to have the control section on the left hand side, whereas a typical CMS sign usually has the control section on the right hand side. The control location on the CMS sign can not be switched on the stocked or readily available CMS sign. Accordingly, a CMS to be placed in the median may take more than twice the normal time for the manufacturer to develop and ship.

5.2.1 LOCATION

The designer shall consult the District Traffic Operations, TMC Support for sign type and exact location of the CMS structure. Additionally, the CMS structure must be outside of the Clear Recovery Zone. In situations where this would not be possible, then the pole shall be protected.

The designer should provide sufficient time for HQ Structures Maintenance staff to design the CMS structure and foundation.

5.2.2 CONTROLLER

The CMS controller assembly is housed in a State furnished model 334 controller cabinet, which should be located 40-60 ft in front of the sign. The CMS controller assembly includes the Model 170 controller, 2 Controller Interface Assembly (CIA) units, analog modem and telephone responder.

5.2.3 POWER

The CMS system shall be designed to operate on a single phase, 120/240 V(ac) service rated at 20 kVA for Xenon or 5 kVA for LED. The typical load for CMS with Xenon is 8 kW and LED is 1 kW. For power requirements and details, refer to “CMS Design Guidelines.”

5.2.4 COMMUNICATIONS

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for communication to/from a roadside CMS.

1. Fiber Optics or Copper infrastructure, where available.
2. Twisted pair or low bandwidth leased services (POTS, Analog 3002. A.D.N.), based on availability.
3. General Packet Radio Service (GPRS), Code Division Multiple Access CDMA or other available wireless service.
4. Digital Subscriber Line (DSL) or other high bandwidth leased services, such as leased Cable TV Service, may be used for backhauling information from a high concentration of different field elements.
5. Agency owned non-licensed Microwave Systems.

5.3 HIGHWAY ADVISORY RADIO

For typical Highway Advisory Radio (HAR) detail, see Sheet E-6.

5.3.1 LOCATION

The HAR should be located where the best propagation of the radio signal will occur. Consideration should be given as to the drivers' ability to safely tune their radio while driving.

The designer shall consult with District traffic operations TMC support for best and exact location.

5.3.2 CONTROLLER

The HAR controller assembly is housed in a contractor-furnished housing and shall be installed per the Standard Plans, "ELECTRICAL SYSTEMS (Controller Cabinet Details)" on a 334 cabinet foundation. Refer to ES-3C of the Standard Plans.

5.3.3 POWER

The HAR system shall be designed to operate on a single phase, 120/240 V(ac). The typical load for this system is 1200 W.

5.3.4 COMMUNICATIONS

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for communication to/from a roadside HAR.

1. Fiber Optics or Copper infrastructure, where available.
2. General Packet Radio Service (GPRS), Code Division Multiple Access or other available wireless service.
3. Digital Subscriber Line (DSL) or other high bandwidth leased services, such as leased Cable TV Services, may be used for backhauling information from a high concentration of different field elements.
4. Twisted pair or low bandwidth leased services (POTS, Analog 3002. A.D.N.), based on availability.

5. Agency owned non-licensed Microwave Systems.

5.3.5 GROUND PLANE

Depending on the type of terrain and amount of space allocated, the Ground Plane can be one of following three types:

1. **Ground Rod:** consisting of a 40 ft ground rod. This is the preferred method.
2. **Radial:** used where the ground is relatively flat and not rocky and where the ground plane can be buried at least 1 ft below original grade (OG). The edges of the ground plane shall be marked with Type K2 markers, in place of yellow retroreflective sheeting; the letters “HAR” shall be used. The antenna pole is placed in the center of the radial.
3. **Multiple Ground Rod:** consisting of multiple (three 20 ft) ground rods connected together. See Sheet E-6.

5.3.6 ANTENNA

The antenna shall be mounted on a fiberglass standard or wood pole. The top of the antenna shall be no higher than 49 ft above the original grade.

5.4 EXTINGUISHABLE MESSAGE SIGN

The Extinguishable Message sign (EMS) system is furnished and installed by the contractor as a complete and operational system. The EMS shall use LEDs and the message will read “Tune Radio to XXX AM”. The XXX will be replaced with the transmitting frequency of the HAR.

5.4.1 LOCATION

The EMS should be located approximately 1.5 to 2 miles from an existing or new HAR.

5.4.2 EQUIPMENT

The EMS should be mounted on the sign structure as shown in the Standard Plans. In situations where there is limited room or other concerns, the designer should consult the Electrical Design Branch Chief for the type of post and mounting preference and shall show the installation details on the plans.

5.4.3 POWER

The EMS system shall be designed to operate on single phase, 120/240 V(ac) service with a typical load of 500 W.

5.4.4 COMMUNICATION

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for communication to/from a roadside EMS.

1. Fiber Optics or Copper infrastructure, where available.
2. Existing Digital Subscriber Line (DSL) or other high bandwidth leased services, such as leased Cable TV Services, may be used for backhauling information from a high concentration of different field elements.
3. General Packet Radio Service (GPRS), Code Division Multiple Access or other available wireless service.
4. Twisted pair or low bandwidth leased services (POTS, Analog 3002. A.D.N.), based on availability.

5. Agency owned non-licensed Microwave Systems.

5.5 ROADWAY WEATHER INFORMATION SYSTEM

For typical Roadway Weather Information System (RWIS) detail, see Sheet E-7.

The RWIS equipment should include installation of a camera on the tower to give the Transportation Management Center (TMC) a visual verification of RWIS data. The RWIS camera shall conform to the CCTV specifications. For a sample design, see the electrical plan titled “RWIS” in this Design Guide.

5.5.1 LOCATION

The RWIS equipment tower should be located where it will get the maximum exposure to the weather (i.e. wind direction and speed, rain, snow and temperature variations). The tower should be located in an area where it is accessible to maintenance and will not create a traffic safety hazard.

5.5.2 CONTROLLER

The RWIS cabinet shall be installed per the Standard Plans, “ELECTRICAL SYSTEMS (Controller Cabinet Details).”

5.5.3 POWER

The RWIS system shall be designed to operate on a single phase, 120/240 V(ac). Typical load for this system is 500 W. The design engineer should consider the additional load of the CCTV where applicable.

5.5.4 COMMUNICATIONS

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for communication to/from a roadside RWIS.

1. Fiber Optics or Copper infrastructure, where available.
2. General Packet Radio Service (GPRS), Code Division Multiple Access or other available wireless service.
3. Twisted pair or low bandwidth leased services (POTS, Analog 3002. A.D.N.), based on availability.
4. Satellite communication for remote rural areas where other services are unavailable.
5. Digital Subscriber Line (DSL) or other high bandwidth leased services, such as leased Cable TV Services, may be used for backhauling information from a high concentration of different field elements.
6. Agency owned non-licensed Microwave Systems.

5.5.5 ROADWAY SENSORS

Roadway sensors should be installed in all lanes in a staggered formation to prevent interference with each other. The sensors are usually installed in the roadbed and sometimes on the bridge deck. If the sensors have to be installed on a bridge deck, then the designer shall consult with HQ Structures Maintenance for coordination of work. Since RWIS sensors are vendor-specific, the designer should contact the sensor vendor for details.

5.6 TRAFFIC MONITORING STATION / VEHICLE DETECTION STATION

When modifying an existing Traffic Count Stations or Traffic Census Stations, they shall be upgraded to a traffic monitoring station/vehicle detection station.

The designer shall verify and include existing TMS elements within project limits, even if they do not conflict with proposed work.

For lengthy construction, traffic monitoring stations shall remain in the operating condition, except:

1) for a duration of up to 2 weeks, on any continuous segment of the freeway/highway longer than 3 miles
2) for a duration of up to 2 months, on any continuous segment of the freeway/highway shorter than 3 miles

The designer shall include stage construction plans to keep detection during construction as required by the Directory Policy memo DP-26.

5.6.1 INDUCTIVE LOOPS

Inductive loops are commonly used for traffic monitoring.

5.6.1.1 LOCATION

The loops are to be placed on the mainline at a location where they can detect the flow of traffic. They should be in a location where the traffic is not weaving or merging, i.e. away from on and off ramps.

5.6.1.2 CONTROLLER

The State-furnished Model 170-controller assembly shall be housed inside a model 334 cabinet.

5.6.1.3 POWER

The traffic monitoring station system shall be designed to operate on a single phase, 120/240 V(ac). The typical load for this system is 500 W.

5.6.1.4 COMMUNICATIONS

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for communication to/from roadside Traffic Monitoring Station / Vehicle Detection Station.

1. Fiber Optics or Copper infrastructure, where available.
2. Existing Digital Subscriber Line (DSL) or other high bandwidth leased services, such as leased Cable TV Services, for backhauling information from a high concentration of different field elements.
3. General Packet Radio Service (GPRS), Code Division Multiple Access or other available wireless service.
4. Twisted pair or low bandwidth leased services (POTS, Analog 3002. A.D.N.), based on availability.
5. Satellite communication for remote rural areas where other services are unavailable.
6. Agency owned non-licensed Microwave Systems.

5.6.2 MICROWAVE VEHICLE DETECTION SYSTEM, SIDE FIRING

The Microwave Vehicle Detection System (MVDS) is furnished and installed by the contractor as a complete and operational system including the pole, MVDS unit, MVDS back board, power supply, MVDS cabinet when needed, mounting brackets, connectors and hardware, MVDS cable (12 twisted pair, No. 18 AWG multicolored pairs) and other conductors. The contractor shall provide video proof and documentation of the MVDS' performance to specifications.

For a typical MVDS detail, see Sheets E-8 and E-4.

The design engineer should evaluate the MVDS advantages/disadvantages as they apply for a specific site before determining whether MVDS is appropriate for that location. In addition, the design engineer should contact operations staff to figure out whether MVDS is suitable. The following are the major advantages/disadvantages of MVDS:

Advantages:

- **Road Closures usually not needed:** The main advantage of MVDS is that it can be installed generally without any road closure/traffic control. The equipment is installed on poles or structures at the side of the roadway. In addition, avoiding cuts in the roadway extends the life of the pavement.

- **Detection during Construction:** Continued vehicle detection data during construction has become critical in light of Director's new policy memo DP-26. MVDS is particularly suitable for temporary detection when loop detectors become damaged (and inoperable) during construction projects. Long-term construction projects also need to incorporate a back-up detection plan that utilizes alternate method such as MVDS.

- **Easy Installation:** MVDS is easiest and fastest detector to install. MVDS should be considered where detection is needed immediately.

- **Detection on Structures:** MVDS is recommended for highway surveillance for freeway to freeway interchanges and other long structured bridges where metallic re-bars affect the magnetic properties of the loop detectors. If there is a power and an existing pole on the structure, the MVDS equipment can be attached to the pole. The Caltrans Structures also discourages placing loops on structures and bridges.

- **Detection on Limited Right of Way:** MVDS is recommended for really tight bottlenecks where cabinet installation and access are major issues.

- **Re-Installation:** MVDS can be re-installed easily. These units could be continuously recycled to less dense locations, as more accurate detectors supplant them in more heavily congested areas.

- **Detection in Distressed Pavement:** Older loop detectors in distressed pavement may be dysfunctional and might produce bad or no data. MVDS detection is independent of pavement condition.

- **Cost Effective in Some Situations:** Since most of the MVDS installations don't require any lane closures and traffic control, so it is cost effective when used for three to eight lanes of traffic. The loops are less expensive for less than three lanes of traffic unless those are heavily traveled lanes.

Disadvantages:

- **Traffic Signal/Ramp Metering Control:** MVDS is less accurate at slow speeds and its inability to hold presence of the vehicles makes it unacceptable for traffic signal and/or ramp metering control. In addition, MVDS is not accurate especially for left hand turn lanes. MVDS is best suited for highway data collection and surveillance.

- **Less Accurate:** MVDS is less accurate than properly installed loops, with comparison detailed in MVDS guidelines. MVDS accuracy is a function of setup geometry, which should be optimized before installation. Then it should be tweaked by a technical professional in the field to reach an optimum level of accuracy.

- **Tunnels, Tubes and Enclosed Roadways:** MVDS is unsuitable due to inadequate setback and reflections off walls and ceilings.

- **Occlusion:** MVDS can't count some vehicles which are hidden by the semi-trucks or other larger vehicles in the next lanes. Occlusion gets worse with the increase in the number of lanes.

- **Technical Challenges:** MVDS should be avoided in locations where metallic items like chain link fence or sign truss can deflect the radar beam.

The design engineer should refer to the “Detector Evaluation and Testing Team” report dated January 15, 2004, for additional information.

5.6.2.1 LOCATION

The MVDS pole shall be outside of the Clear Recovery Zone. The designer must consider two factors for location and positioning of side-fired MVDS:

1. Number of lanes to be monitored in relation to the set back of the mounting pole.
2. Presence and width of barriers and their related shoulders.

To reduce occlusion, the recommended MVDS set-back and mounting height from the edge of the traveled way (ETW) is shown in the following table:

Table 8. Pole Set-Back and Mounting Height

Number of Lanes	Set-Back ft	Mounting Height ft
2	10	15
4	15	17
6	20	19
8	25	21
10	30	23

The designer should refer to the MVDS Design Guidelines.

5.6.2.2 CONTROLLER

The stand-alone MVDS controller assembly is housed in a contractor furnished Type B TDC cabinet. If a MVDS is used in conjunction with other TMS elements, then the State furnished Model 334 controller cabinet can be used to house the MVDS equipment.

5.6.2.3 POWER

The MVDS backboard can feed from either the 120 V(ac) power supply in the cabinet, or be solar powered. The typical load for this system is 500 W.

5.6.2.4 COMMUNICATIONS

Consult with District Traffic Operations, TMC Support for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice for communication to/from a roadside MVDS.

1. Fiber Optics or Copper infrastructure, where available.
2. Digital Subscriber Line (DSL) or other high bandwidth leased services, such as leased Cable TV Services, for backhauling information from a high concentration of different field elements.
3. General Packet Radio Service (GPRS), Code Division Multiple Access or other available wireless service.
4. Twisted pair or low bandwidth leased services (POTS, Analog 3002. A.D.N.), based on availability.
5. Agency owned non-licensed Microwave Systems.
6. Satellite communication for remote rural areas where other services are unavailable.

5.6.3 AUTOMATIC VEHICLE CLASSIFICATION STATION

Automatic Vehicle Classification (AVC) System mainly consists of AVC unit including modem, antenna assembly, type “M” cabinet, inductive loop detector, piezo-electric axle sensors, pull boxes, conduits and conductors.

Piezo-electric axle sensors include a screened transmission cable. The sensors should be installed in an array of one inductive loop detector and two axle sensors per lane. For typical AVC layout, see figure below.

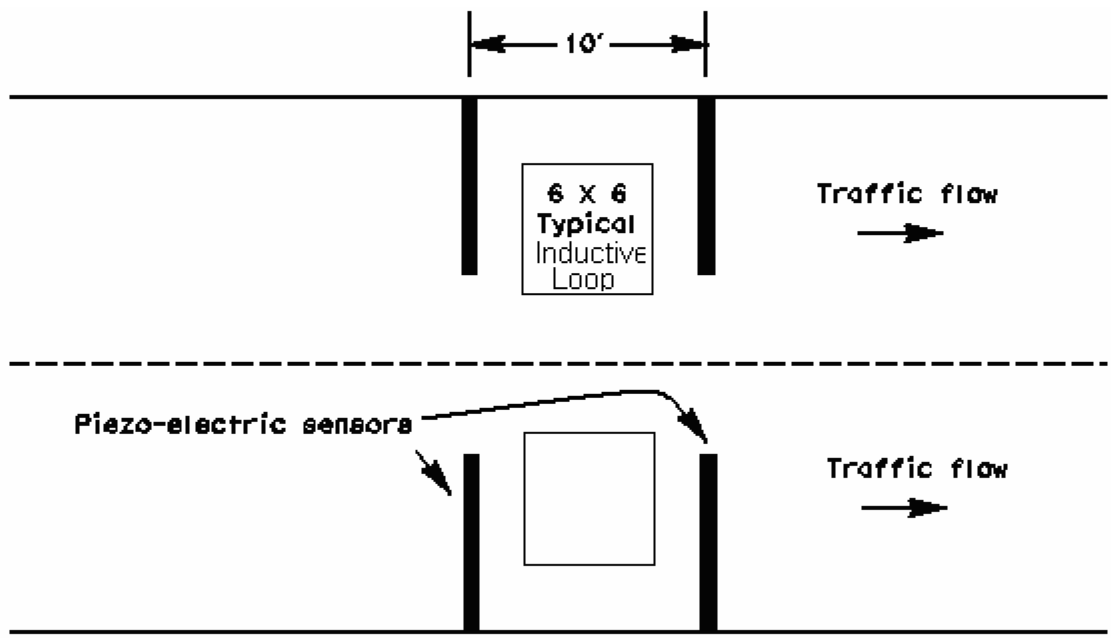


Figure 6. Piezo-electric Sensors

The AVC is requested by the District census coordinator or HQ census coordinator.

5.6.3.1 LOCATION

The loop and piezo-electric sensors are to be placed on the mainline, where the roadway is straight and the flow of traffic is not likely to be changing lanes or weaving away from entrance ramps, exit ramps, interchanges and curves. The piezo-electric sensors should be roughly two thirds (2/3) of the width of the traveled way. The exact location of AVC shall be provided by the District census coordinator.

5.6.3.2 POWER

The AVC system shall be designed to operate on a single phase; 120/240 V(ac). Typical load for this system is 20 W.

5.6.3.3 COMMUNICATION

Consult with District census coordinator for preferred communication methods based on compatibility to the existing infrastructure. The choice of the communication method will also depend on the geographic location and service availability in the area. Overall preferred communication methods are listed in the order of choice from AVC to the District census coordinator's office.

1. Twisted pair or low bandwidth leased services, based on availability.
2. General Packet Radio Service (GPRS), Code Division Multiple Access or other available wireless service.
3. Satellite communication for remote rural areas where other services are not available.

5.7 RAMP METERING SYSTEM

For Ramp Metering System (RMS), the design engineer should refer to "Ramp Metering Design Guidelines." Ensure installation of a 310 W HPS electrolier at the ramp metering limit line. Consult your Electrical Design Branch Chief.

6.0 FIBER OPTIC DETAILS

The design engineer should refer to the Fiber Optic Design Guidelines (version 1.0, Oct 1998 or later) for additional information.

6.1 GENERAL

It is important to provide a splice closure in the local vaults. The Fiber Optic (F/O) drop cable and Fiber Optic Distribution Unit (FDU) should be provided in the equipment enclosure. Check to see that the equipment enclosure and FDU will accommodate the specified F/O drop cable. It may be necessary to provide a smaller drop cable instead of running directly into or through the equipment cabinet. The State will provide the electronics and connect the equipment to the contractor-furnished FDU. The fiber optic cable shall be terminated in the FDU. Refer to the Fiber Optic Design Guidelines.

6.2 CONDUITS

For F/O drop cable, the conduit size 1-1/4” can be installed without pull boxes, directly from the vault into the equipment enclosure. The 1-1/4” conduit is a High Density Polyethylene (HDPE) that has long sweeps (bends), allowing it to be installed without pull boxes.

If possible, do not place F/O cable and electrical wiring in the same pull box, as it is possible to damage the F/O cable without any outward physical signs. If F/O cable must be placed in a common pull box with electrical wiring, provide a physical barrier (i.e. orange Electrical Non-metallic Tubing or ENT).

6.3 EXISTING EQUIPMENT

It is important to provide conduit, F/O drop cables and FDU to all existing equipment.

6.4 SPLICE DETAILS

The design engineer, in coordination with the District Traffic Operations, TMC Support, should include splice details in the plans. At a minimum, the special provisions should indicate that it will be provided by the engineer during construction.

6.5 VAULTS AND PULL BOXES

The specified 4 x 4 x 5 ft vaults are to be spaced at intervals of approximately 2460 ft to 3281 ft or more. Long straight freeway conduit runs allow for vault spacing that is limited only by the F/O cable lengths (up to 3.1 mile).

The exact station and finished grade (FG) elevation of the centerline of the vault cover is to be shown on the plan. The vaults are to be engineered into the roadway geometry and may require integration with the other roadway facilities. The vaults, with their conduits and slurry or concrete backfill, may need to be placed in more than one operation, and coordinated with guardrail, structures, or drainage facilities in order to avoid conflicts.

In urban areas, vaults shall be placed approximately at the interchange.

The vaults should be uniquely identified on the plans and in the field using a numbering system based on Co-Rte-PM similar to that used in highway lighting and Type K-2 markers (Standard Plan A73B) with no reflectorization.

The number for the vaults can be cast into the concrete cap. No vaults or pull boxes should be used between the splice vault and the equipment enclosure.

6.6 FIBER ELECTRONICS

The design engineer should contact District Traffic Operations, TMC Support to determine what fiber electronics will be needed. The installation of FDUs should be clearly stated on plans.

6.7 FIBER OPTIC TESTING

The preferred method of testing is the end-to-end attenuation testing, using a power meter and light source. This method measures the total optical power loss from connector to connector. Fiber performance worksheets should be used to ensure minimum system performance margin of 6 dB. For details, refer to Fiber Optic Design Guidelines.

7.0 APPENDICES

APPENDIX A	Memorandum: MODEL 170 CONTROLLER ASSEMBLY COST PARTICIPATION POLICY	Dated August 10, 1988
APPENDIX B	Memorandum: BREAKAWAY/SLIP BASE UNDER ELECTROLIERS LOCATED ALONG FREEWAYS, EXPRESSWAYS, AND CONVENTIONAL HIGHWAYS	Dated October 30, 1987
APPENDIX C	Memorandum: ITS Policy	Dated August 04, 2006
APPENDIX D	Memorandum: LIGHTING FOR NONSTANDARD SAG VERTICAL CURVES	Dated June 16, 1993
APPENDIX E	Memorandum: CLARIFICATION ON LIGHTING OF SAG VERTICAL CURVES WITH NONSTANDARD STOPPING SIGHT DISTANCE	Dated May 11, 1993
APPENDIX F	Memorandum: SUPPLY LINES, COMMUNICATION CONDUIT AND SPRINKLER CONTROL CONDUIT ON BRIDGES	Dated December 1990
APPENDIX G	Memorandum: CLARIFICATION OF VOLTAGE DROP CALCULATION	Dated April 4, 1995
APPENDIX H	List of Manuals and Website	
APPENDIX I	List of State Furnished Equipment	
APPENDIX J	X-Form	
APPENDIX K	Circuit Breaker Curve	
APPENDIX L	Glossary	
APPENDIX M	Acronyms, Abbreviations and Symbols	
APPENDIX N	Highway Utilities Process: Telephone	
APPENDIX O	Highway Utilities Process: Electric	

APPENDIX A: Cost Participation for Model 170 Controller Assembly

State of California Business, Transportation and Housing Agency

Memorandum

To All District Traffic Engineers Date August 10. 1988

From **DEPARTMENT OF TRANSPORTATION**
Division of Traffic Engineering

Subject Cost Participation for Model 170 Controller Assembly

Attached is the Policy for Cost Participation for Model 170 Controller Assembly between the Stare and a local agency, or a private party.

The Policy defines the conditions under which the State will:

a) furnish without charge;

b) share the cost for; or,

c) not share the cost for

the Model 170 Controller Assembly of a signal, and as such, supplements Section 9-13.2 of the Traffic Manual and Bob Adams' Model 170 Controller Assemblies Policy Memorandum dated August 29, 1983.

If you have any questions, please call Kwan Lau of my staff at 8-485-2577.

R. L. DONNER, Chief
Office of Electrical Systems

Attachment

CKL/js
bcc: CKLau,
CPerry
KGilbert
WHoversten
NWingerd
Traffic Files

Model 170 Controller Assembly Cost Participation Policy

(References: Traffic Manual – Section 9-13.2 and, Model 170 Controller Assemblies Policy Memorandum, Dated August 29, 1983)

Type of Signal Project	Located on State Highway	Project Financed By	Who Supplies	Who Pays	% State Participation
New or modified	**Yes**	**State**	**State**	**State**	100%
New or modified	**Yes**	**State and Local**	**State**	**Both**	(2)
New	**Yes**	**Local**	**(4)**	**(4)**	(4)
Modified	**Yes**	**Local**	**Local (1)**	**Local (1)**	0%
New	**Yes**	**Private**	**Private**	**Private**	0%
Modified	**Yes**	**Private**	**Private(1)**	**Private (1)**	0%
New or Modified	**No**	**Local or Private**	**Local or Private**	**Local or Private**	0%
Coordination (5)	**No**	**State and Local**	**State**	**Both**	(2), (3)
Coordination (5)	**No**	**Local**	**Local (3)**	**Local (3)**	(3)

(1) Where relocation of an existing non- 170 is required as part of the work, the State will furnish a new 170 assembly at 100% State expense if such replacement is to the benefit of the State.

(2) In accordance with the terms of the Cooperative Agreement.

(3) The State may supply a 170 Assembly at no cost to the local agency where the State will benefit by reducing congestion on the State highway. Written approval from Headquarters Division of Traffic Operations is required.

(4) New intersection: Local, Local, 0%. Existing intersection that meets warrants: State, State, 100%.

(5) Where a non-State signal is to be coordinated with a State signal.

APPENDIX B: Breakaway/Slip Base Under Electroliers Located Along Freeways, Expressways, and Conventional Highways

State of California Business, Transportation and Housing Ager

Memorandum

To All District Traffic Engineers
All Electrical Design Engineers

Date October 30. 1987

From **DEPARTMENT OF TRANSPORTATION**
Division of Traffic Engineering

Subject Breakaway/Slip Base Under Electroliers Located Along Freeways. Expressways and Conventional Highways

BREAKGROUND

There are presently two types of slip bases for electroliers shown in our Standard Plans. These are the slip base and the slip base insert. Breakaway type bases were installed under electroliers as far back as the mid-sixties to minimize injuries to occupants of vehicles and damage to vehicles by enabling the poles to yield or break away from the foundations when hit by the vehicles. The initial "breakaway" was a six-inch cast aluminum insert introduced shortly before 1966. This was followed by the "transformer-type" base in 1966. In 1969, slip bases and slip base inserts were added to our Standard Plans.

PURPOSE

To establish design criteria for the installation of breakaway/slip bases and slip base inserts for new or existing electroliers located on freeways, expressways and conventional highways.

DESIGN

Design Criteria

New Installations:

a. Freeways

Slip bases shall be used under Types 30 and 3 1 standards on freeways. freeway ramps and collector roads where the prevailing speed is in excess of 40 miles per hour. Slip bases or slip base inserts shall be used under Type 15 standards located on freeway ramps and collector roads within an interchange area where the prevailing speed is in excess of 40 miles per hour.

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> Slip bases or slip base inserts shall be used under lighting standards located at a non-signalized intersection of a freeway ramp with a local street or a conventional highway

where the posted speed limit on the local street or the conventional highway is greater than 40 miles per hour.

Exceptions to this policy are that slip bases or slip base inserts are not to be used under lighting standards located:

1. on or behind structures, retaining walls or barrier railings:

2. in sidewalk areas:

3. behind guardrail:

4. more than 30 feet from the traveled way; or

5. where pedestrians would be close enough to be endangered by a pole knockdown.

B. Expressways

Slip bases or slip base inserts shall be used under lighting standards located on the right shoulders of expressways where the posted speed limit on the expressway is in excess of 40 miles per hour.

Slip bases or slip base inserts shall be used under lighting standards located at the intersection of an expressway (or a ramp from an expressway) with a local street or a conventional highway where the posted speed limit is greater than 40 miles per hour.

Exceptions to this policy are that slip bases or slip base inserts are not to be used under lighting standards:

1. that have signal heads:

2. located on or behind structures, retaining walls or barrier railing:

3. located in sidewalk areas:

4. located behind guard rail:

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5. located more than 30 feet from the traveled way: or

6. located where pedestrians would be close enough to be endangered by a pole knockdown.

c. Conventional Highways

Slip bases or slip base inserts shall be used under lighting standards located on the right shoulders of conventional highways where the posted speed limit on the highway is in excess of 40 miles per hour.

Slip bases or slip base inserts shall be used under lighting standards located at the intersection of a conventional highway with another highway or a local street where the posted speed limit is greater than 40 miles per hour.

Exceptions to this policy are that slip base or slip base inserts are not to be used under lighting standards:

1. that have traffic signal heads:

2. located on or behind structures, retaining walls or barrier railing:

3. located in the sidewalk areas:

4. located close to a populated area/facility such that the occupants of the area/facility would be endangered b\ a pole knockdown:

5. located behind guardrailing:

6. located more than 30 feet from the traveled way: or

7. located where pedestrians would be close enough to be endangered by a pole knockdown.

Existing Installations:

All lighting standards that satisfy the conditions noted above under "New Installations" and are within an area of a project that has other highway lighting work should be considered to be modified to include slip bases or slip base inserts, except as noted below.

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Any lighting standard which has been hit repeatedly on is in a particularly vulnerabl location should be eliminated or moved laterally if such a change will not degrade the lighting level, or should be replaced with a standard with longer luminaire arm t be installed further away from the edge of traveled way - Such a standard should b provided with a slip base or a slip base insert if it satisfies the conditions noted above under "New Installations."

Any lighting standard with a 6-inch case aluminum breakaway insert or a "transformer-type breakaway base may remain in place. In the event of a knockdown, a new 6-inch insert or a transformer base may be installed under a nev standard. However, in the interest of standardization, preference should be given tc a slip base insert for the 6-inch cast aluminum breakaway insert and a converted type of slip base for the transformer base if either is readily available and will fit the anchor bolt patterns.

[Original Signed C. D. BARTELL]

C. D. BARTELL, Chief
Division of Traffic Engineering

CKLAL:jmac

bcc: CKLau
JPerry
NWingerd
K Gilbert
Traffic Files

APPENDIX C: ITS Policy

Director's Policy

Number:	DP-26
Effective Date:	August 2006
Supersedes:	NEW

TITLE Intelligent Transportation Systems

POLICY

The California Department of Transportation (Department) implements advanced technology systems and new processes that combine information, electronic and communications technologies with management strategies to develop Intelligent Transportation Systems (ITS). ITS is used to improve the safety and efficiency of transportation systems and mobility throughout the State.

The Department employs ITS Architecture and Transportation Management System (TMS) strategies to produce coordinated and integrated service systems that improve security, performance and cost-effectiveness of transportation services, vehicles, and infrastructure.

INTENDED RESULTS

The intent of this policy is to support deployments of integrated, ITS-based transportation services in the State, allow ITS stakeholders to coordinate services, make the best use of limited resources, and engage in long-term planning for technology solutions to transportation problems.

This policy promotes a more streamlined, information-based transportation network that will enable travel and goods movement throughout the State in a more efficient and informed manner, provides better access to information and historical data, better transportation planning and modeling, and consistency with federal rules and regulations.

RESPONSIBILITIES

<u>Director:</u>

- Creates an environment for effective, cross-functional coordination in which ITS solutions can be successfully delivered.
- Encourages staff development for increased knowledge and expertise in ITS.

<u>Deputy Directors and District Directors</u>:

- Promote ITS and asserts leadership in developing partnerships.
- Facilitate cooperation and coordination between departmental functional areas.
- Ensure that the Department's actions and services are consistent with this policy and federal and State rules and regulations relating to ITS.
- Advocate incorporation of ITS in externally financed projects.

Director's Policy
Number DP-26
Intelligent Transportation Systems
Page 2

Deputy Director, External Affairs:

- Explores opportunities to promote ITS in the media.
- Directs the district public information officers to use ITS for sharing traffic and travel information with the media, including traffic reporters, Internet companies, and telematics service companies.
- Ensures ITS programs, such as traveler services information, are prominently displayed on the Department's web page or other appropriate sites.

Deputy Director, Planning and Modal Programs:

- Ensures development, inclusion, and implementation of ITS policies, guidelines, and strategies in State and regional transportation plans and programs.
- Ensures statewide compliance with federal and State ITS Architecture for continued use of federal and State funds for ITS implementation.

Deputy Director, Maintenance and Operations:

- Operates ITS services and systems for safe, secure and efficient operation and management of the transportation system.
- Leads measurement of transportation system performance to identify operational strategies and opportunities for improvement.
- Implements National ITS standards and specifications related to the design and development of ITS projects.
- Leads research, development, testing, and deployment of ITS technologies and demonstrations.

Chief Information Officer (Deputy Director, Headquarters Information Technology):

- Ensures that Department IT standards and approval processes permit the implementation of national ITS standards.
- Supports system configuration and provides support services for ITS hardware, software and networks.

Chief Engineer (Deputy Director, Project Delivery):

- Ensures ITS solutions, as appropriate, are incorporated in the design and construction of transportation infrastructure and facilities.

Chief, Division of Transportation Planning:

- Mainstreams ITS into State and regional transportation plans and programs.
- Maintains State ITS Architecture and System Plan process.
- Provides assistance to districts and Headquarters programs in implementing State and regional ITS Architecture.
- Administers the ITS training program and professional capacity building.
- Ensures Project Initiation Documents contain necessary ITS elements.

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Number DP-26
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Page 3

Chief, Division of Traffic Operations:

- Develops and deploys ITS projects that implement the ITS user services and the TMS Master Plan.
- Develops standards and specifications related to the design and deployment of ITS projects consistent with National ITS standards.
- Ensures, in coordination with the districts, proposed ITS projects are consistent with State and regional ITS Architectures.
- Coordinates the delivery of ITS services through Memoranda of Understanding with organizations internal and external to the Department.
- Collects and reports operating costs of ITS services and systems.

Chief, Division of Research and Innovation:

- Conducts research, development, and testing of ITS innovations in support of transportation plans and operational needs.

Chief, Division of Transportation System Information:

- Ensures that system performance information and Geographic Information System support ITS activities.

Chief, Division of Maintenance:

- Ensures continued operation of ITS infrastructure.
- Maintains an inventory, costs, and status of system repairs and rehabilitation for ITS field elements.
- Incorporates ITS in development and operation of maintenance equipment.
- Uses field observations and fleet management to collect ITS data.

Chief, Division of Mass Transportation:

- Encourages transit providers to fully consider a variety of ITS tools to improve the efficiency and safety of transit services and operations.

Chief, Division of Rail:

- Ensures that ITS is appropriately considered in statewide decision-making and investment for rail transportation.

Chief, Division of Aeronautics:

- Ensures that ITS is fully considered in statewide decision-making and investment for aviation transportation.

Chief, Division of Environmental Analysis:

- Ensures that ITS applications are considered in the environmental decision-making process and environmental impact documents.

Director's Policy
Number DP-26
Intelligent Transportation Systems
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Chief, Division of Local Assistance:

- Ensures local agency conformity to national ITS Architecture and standards.

Chief, Division of Design:

- Revises manuals and procedures documents to facilitate design standards, specifications, and guidelines for ITS.
- Develops plans and specifications that ensure continued operation of ITS infrastructure during construction.

Chief, Division of Construction:

- Ensures continued operations of ITS infrastructure during construction and approval of ITS elements prior to contract acceptance.

Chief, Division of Project Management:

- Incorporates ITS in the Department's program and project management processes and systems.
- Develops and maintains statewide workload, resource, structure, estimating norms formulas, timelines, and workload distributions for design of ITS projects.

APPLICABILITY

All departmental employees involved in ITS activities.

Will Kempton 8-4-06

WILL KEMPTON Date Signed
Director

APPENDIX D: Lighting For Nonstandard Sag Vertical Curves

Stale of California **Business, Transportation and Housing Agency**

Memorandum

To DEPUTY DISTRICT DIRECTORS, OPERATIONS
DEPUTY DISTRICT DIRECTORS
PROJECT DEVELOPMENT

Date June 16, 1993

From **DEPARTMENT OF TRANSPORTATION**
Division of Traffic Operations

Subject Lighting for Nonstandard Sag Vertical Curves

Attached is. a Memorandum from W. P. Smith. Chief of the Office of Project Planning and Design (OPPD), clarifying the lighting of sag vertical curves with nonstandard stopping sight distance.

When the OPPD Coordinator and the Traffic Liaison Engineer, with input from the district functional units, determine that lighting should be installed, the following guidelines should be used to decide the locations of electroliers:

a) The responsible project engineer (civil) shall provide the actual sight distance from the beginning of the curve and the length of the curve, for each direction of travel, to the electrical engineers doing the lighting design.

b) The first electrolier should be located at the actual sight distance downstream from the beginning of the curve. Additional electroliers should be located at 180-foot intervals to within 90 feet of the end of the curve. (Note that the last electrolier will, in some cases, be beyond the end of the curve.

c) The types of electroliers used should be those with 310-watt HPS luminaire and pole shaft of 35 feet in length.

d) As an example (see attached drawing), if the actual sight distance of the nonstandard vertical curve is 360 feet and the length of the curve is 970 feet for the direction shown. then—

1) The location of the electrolier should be 360 feet (the actual sight distance) from the beginning of the curve. The second electrolier should be 540 feet (360 + 180 feet) from the beginning of the curve. the third 720 feet (540 + 180 feet). and the fourth 900 feet ~720± 180 feet).

DEPUTY DISTRICT DIRECTORS, OPERATIONS
DEPUTY DISTRICT DIRECTORS, PROJECT DEVELOPMENT
June 16, 1993
Page 2

2) Since the last electrolier is within 90 feet from the end of the curve, no additional electroliers are needed.

e) Repeat the same procedure for the opposing direction.

[Original Signed By Robert L. Donner]

ROBERT L. DONNER, Chief
Office of Electrical Systems

Attachments

bcc: JBBolden
RLDonner
CKLau
CPerry
WPSmith - OPPD
GCorrigan - Office Engineer
WHoversten
KNystrom
NWingerd
Ops
Read

Sag Vertical Curves/Lau

APPENDIX E: Clarification on Lighting for Nonstandard Sag Vertical Curves with Nonstandard Stopping Sight Distance

To PROJECT DEVELOPMENT COORDINATORS
GEOMETRIC REVIEWERS, AND
TRAFFIC LIAISON ENGINEERS

Date May 11, 1993

From **DEPARTMENT OF TRANSPORTATION**
DIVISION OF STATE AND LOCAL PROJECT DEVELOPMENT - OFFICE OF PROJECT PLANNING AND DESIGN

Subject Clarification on Lighting of Sag Vertical Curves with Nonstandard Stopping Sight Distance

The language contained in the Highway Design Manual (HDM). Section 201.5 suggests that lighting may be considered when headlight sight distance is not obtainable at grade sags. It has been an informal practice to provide this lighting under these conditions without consideration of long—term maintenance and operations cost or an analysis of the accident history. In cooperation with the Division of Traffic Operations, agreement has been reached on the process of handling future projects when nonstandard stopping sight distances are a factor.

The following actions will be taken to help clarify procedures:

1. A sentence will be added to HDM Section 201 5: The OPPD Coordinator and the Traffic Liaison Engineer shall be contacted to review any proposed grade sag lighting to determine if such use is appropriate.

2. The OPPD Coordinator and the Traffic Liaison Engineer shall work closely in determining whether lighting is appropriate on a case-by-case basis and shall inform the District of the decision. This decision shall be final and shall not be the subject of review by either Headquarters or the District functional units.

3. All situations having nonstandard grade sag sight distance shall have the appropriate documentation, even if there is a decision to provide lighting as a mitigation to the reduced headlight sight distance.

4. There may be cases where a District has decided to install lighting for reasons other than mitigating a non-standard mandatory feature. These decisions shall remain a District decision as per the 1988 delegations.

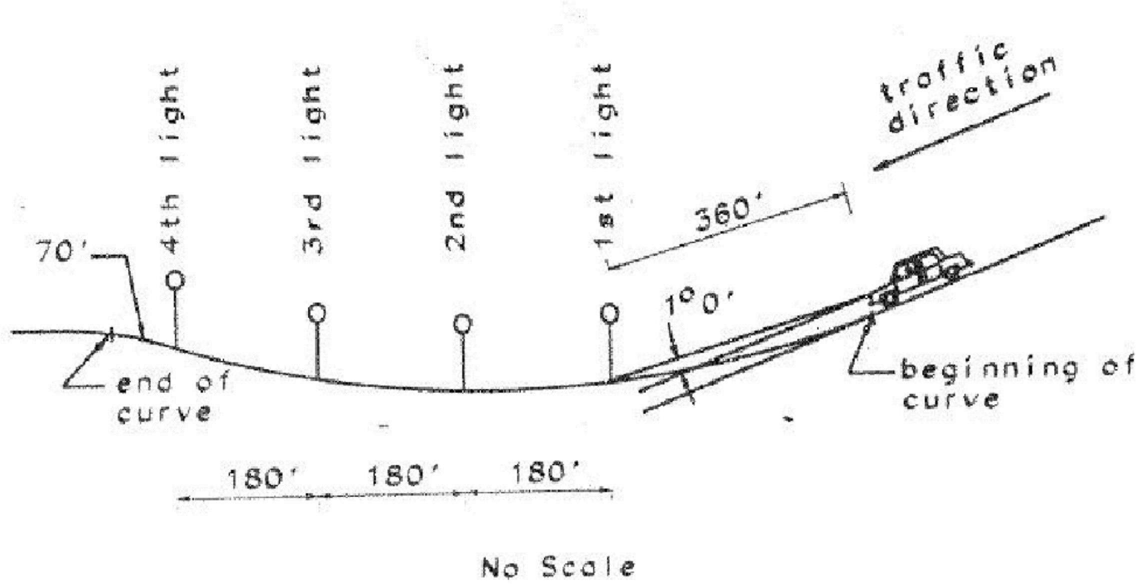
If you have any questions please call Alan Glen, Chief, Geometric Design and Standards Branch, at 263-1042 or Calnet 435-1042.

AGlen:jl
cc: JBorden
BDonner
WSmith, EPMarshall
AGlen, OPPD File

[original signed by W. P. Smith]

W. P. SMITH, Chief
Office of Project Planning and Design

Clarification On Lighting For Nonstandard Sag Vertical Curves With Nonstandard Stopping Sight Distance.



APPENDIX F: Supply Lines. Communication Conduit and Sprinkler Control Conduit on Bridges

Supply Lines, Communication Conduit and Sprinkler Control Conduit on Bridges

Supply Line and Sprinkler Control Conduit

1. The Headquarters Landscape Architect or the District will return a print of the General Plan to the Office of Structure Design and the District Traffic Engineer with comments on supply lines and conduits required for irrigation. General Plans for bridges on which no pipes are anticipated will also be returned so noted.

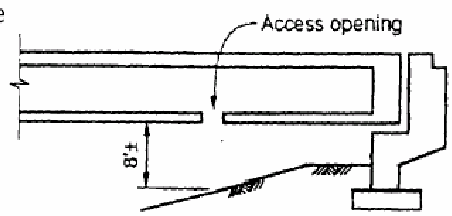
2. Unless otherwise noted by the comments, the Office of Structure Design will furnish a 3" standard galvanized steel pipe for supply lines. Pipe diameters less than 4" can be furnished with the use of Standard Plan B 14-3. For pipes 4" or larger, use Standard Plan B 14-4. All details of the supply lines shall be reviewed by our Mechanical Engineers.

3. Expansion assemblies for supply lines and electrical conduit shall be provided according to bridge length as follows:

   a) Up to 600 feet - one assembly placed at each abutment and another only near an expansion joint if a bridge expansion joint is required.

   b) Over 600 feet - one assembly placed at each abutment and equally spaced at approximately 300 foot intervals preferably near bridge expansion joints.

   Access openings to these expansion joints shall be located in the bottom slab, at the abutment end of each box girder cell which contains supply lines. The opening shall be offset from the utilities and placed a sufficient distance from the abutment to prevent unauthorized access. Access to other expansion assemblies may be gained through openings in caps and diaphragms. Access openings near bents adjacent to expansion joints are permitted if openings in bent caps are impossible. Detail openings on the plans.



4. A supply line pipe is not permitted in any bridge barrier.

Supersedes Memo to Designers I 8-3 dated October 1988

5. The supply line will be carried as a bridge item in the Engineer's Estimate. For estimating, give the total length of pipe (linear feet). Items such as pipe cradles, inserts, bolts, access doors, hangers and expansion assemblies will be included in the price paid per linear foot.

6. Occasionally we have requests from the Landscape Architect to carry a sprinkler control conduit in addition to the water supply line across the structure. This conduit should be handled similar to that for Communication Conduits except the Districts' pay item will be "Sprinkler Control Conduit" The supply line and conduit should cross the bridge in the same general area. The minimum size conduit will be 2".

Communication Conduit

The need for communication lines and their size will be determined by the Districts. The Office of
Structure Design will work with the Districts in determining the exact location within the structure to carry the conduits. The conduits should be placed in the bridge railing or sidewalk if at all possible. If this is done, no detailing is required on the bridge plans and all plans will be prepared by the District. If placed elsewhere, the following items shall be considered:

I . The communications conduit will normally be a District item. Keep separate from other items so that Estimating can distinguish District pay items.

2. All openings shall be fully detailed on the Bridge Plans. We should review the Road Plans to be sure they show the communications conduit and make reference to the details shown on the Bridge Plans.

3. The quantity estimator should take off the linear feet of conduit from pull box to pull box at the ends of the bridge.

4. A pull box is required in the structure every 200'. Where a conduit is used in the railing, the standard electrical pull box can be used. Where larger conduits are required, a special pull box in the soffit can be used where it can be reached without interfering with traffic. For special box details the designer should consult with our Electrical Engineer.

5. Conduits can be cast within various concrete sections where room permits. Expansion fittings for various sizes of conduits have the following outside dimensions:

Conduit Size	Expansion Fitting Outside Dimension
1"	2-5/8"'
1-1/2"	3-1/2"'
2"	4"
3"	5-5/8""

MEMO TO DESIGNERS 18-3 DECEMBER 199

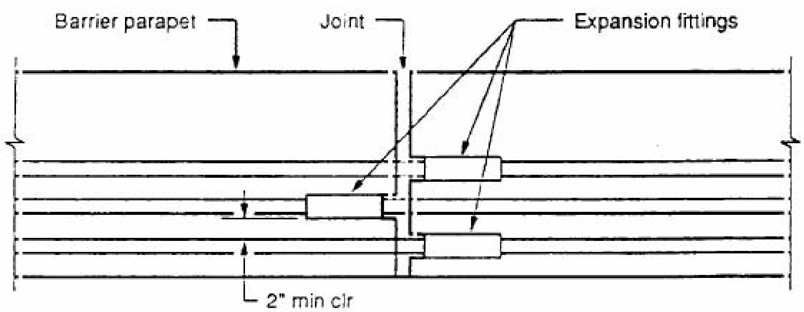
A barrier parapet can readily accommodate a 3″ conduit as shown on Standard Plan B 14-3. However,
if more conduits are required in a standard Type 25 barrier, the following combinations may be used:

1. One 3″ and one 1-1/2″ or 2″″ conduit.

2. Three 1-1/2″ conduits.

2. 3. 3. Adjacent conduits shall have 2″ minimum clear distance between them. When multiple conduits are used, expansion fittings at barrier joints shall be shown on the plans and staggered as shown below.

4.



ELEVATION

If a lighting conduit is to be placed within the parapet it may be necessary to place the communications conduit elsewhere. Keep in mind that the additional short lighting conduit lengths from pull boxes to soffit lights, signs, or electroliers can cause congestion in the parapet.

Expansion fittings are not suitable if barrier has both deflection and expansion.

Joint seals may conflict with placement of conduits in the barriers. *Refer to Standard Plan B6-21 for probable joint seal posit on in barrier.*

[original signed by Floyd L. Mellon and Guy D. Mancarti]

Floyd L. Mellon Guy D. Mancarti

JPH:jgf
Attachment

APPENDIX G: Clarification of Voltage Drop Calculation

OFFICE MEMO Date: *April 4,1995*

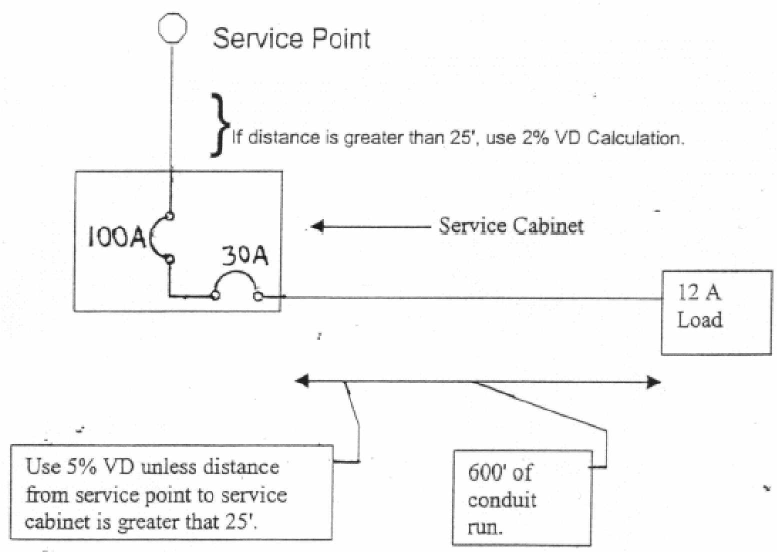
STAFF
Electrical Design

From **DEPARTMENT OF TRANPORTATION**
District 3- Electrical Design/Operations

Subject Clarification of Voltage Drop Calculation

This office memo is to clarify the method in calculating voltage drop. The Electrical Design Branch will now use the criteria stated below:

1. Use the Voltage Drop Calculation stated in the Traffic Manual.
   VD=2IRL, R=VD/2IL
2. The Voltage Drop Calculation should be connected load only.
3. If the distance from the Service Point to the Service Cabinet is less than 25', you should consider this distance as negligible and calculate a 5% Voltage Drop from the Service Point to the Load.
4. If the distance from the Service Point to the Service Cabinet is greater than 25', calculate 2% Voltage Drop for the Service Feeder and 3% Voltage Drop for the Load Feeder.



If you have any questions, please call me at *4370.*

David A. Gamboa, Chief
Electrical Design/Operations

APPENDIX H: List of Manuals and Website

The following are some useful references.

MANUALS

California MUTCD (superseded the Traffic Manual, 1996)
Highway Design Manual (HDM)
The Plans Preparation Manual
Construction Manual
Highway Advisory Radio Design and Operations Guide
Signals Operation Manual, 170-controller (C8)
Fiber Optic Design Guidelines
Ramp Meter Design Manual
Transportation Electrical Equipment Specifications (TEES)
Traffic Signal Control Equipment Specification
IES Lighting Handbook
Post Mile Log
National Electrical Code (NEC)
California Electrical Code (CEC)

WEBSITES - OTHER RESOURCES OF INFORMATION

California Dept. of Transportation	http://www.dot.ca.gov
Caltrans Onramp	http://onramp
Division of Engineering Services	http://www.dot.ca.gov/hq/esc/
Plans Preparation Manual	http://www.dot.ca.gov/hq/oppd/cadd/usta/ppman/default.htm
Policy on High and Low Risk Underground Facilities	http://www.dot.ca.gov/hq/oppd/pdpm/apdx_word/apdx-ll.doc
Traffic Operations, Office of ITS Development and Support	http://www.dot.ca.gov/hq/traffops/elecsys
Northern Region Design and Engineering Services	http://northregion.dot.ca.gov/design/index.htm
California MUTCD	http://www.dot.ca.gov/hq/traffops/signtech/mutcdsupp/ca_mutcd.htm
Federal Highway Dept. of Transportation	http://mutcd.fhwa.dot.gov
The National Technical Information Service	http://www.ntis.gov
CA Public Utilities Commission	http://www.cpuc.ca.gov/
Performance Management System (PeMS)	http://pems.eecs.berkeley.edu/Public/

APPENDIX I: State Furnished Equipment

The following is a list of commonly used electrical equipment that is State Furnished Material (SFM).

The Performance Improvement Initiative (PII) technical team that periodically reviews the SFM list may add or delete some items. The Designer should check the latest SFM items at http://www.dot.ca.gov/hq/esc/oe/awards/#item_code

List of Commonly Used State Furnished Items.

Part No.	Model/Type	Description	Price *
7440-0179 7	332	Signal Cabinet (170/2070)	3032.00
7440-0673 5	-	Battery Backup System for Signals	1387.00
7440-0100 1	334C	Controller Cabinet (170), Ramp Meter, Traffic Count, CMS, TMS	2422.00
7440-0173 4	170E	Controller Unit	827.00
7440-0189 8	2070L	Controller Unit	2000.00
7440-0350 0	222	2-Ch. Loop Detector	43.00
7440-0475 5	242	Dual Isolation Module D.C.	23.00
7440-0196 3	252RR	2-Ch. Isolating Module Railroad	45.00
7440-0290 2	200	Switchpack	16.00
7440-0130 4	400	Modem	85.00
7440-0550 5	420	Auxifile, Output File #2k	278.00
7440-0131 6	Harness	C2P Modem Harness	25.00
7440-0430 0	232E	Dual Magnetic Amplifier Module	436.00
7440-0400 7	231	Magnetic Detector Probe	81.00

* Price subject to change

APPENDIX J: X-Form

(NOTE: Use Your Own District's Established Forms)

(CT) LOCATION NO.__________ *X-FORM, Page 1*

CALTRANS ELECTRICAL PROJECT

This form is to be completed by TELCO Outside Plant Engineer and contains all the necessary information regarding the POINT OF DELIVERY (demarcation box or housing) and SERVICE POINT (terminal). Information determined to be provided by Caltrans is identified as '**CT'** in the left margin and information provided by **Telephone Company** is identified as '**Telco'** in the left margin. Please print information legibly.

TELCO:
OSP Construction Required YES: __________ NO:_________
Job Number ________________ Days Required:____________
Comp. Date (if known)_________

(CT) CALTRANS: (if known)
District_____ County_________ Route ______ Post Mile _____
Contract Number: ____________

A. POINT OF SERVICE DELIVERY*:* (demarcation box or housing)

(CT) 1. Place Demarcation Box ______ or Housing________________

(CT) & (Telco) 2. Location of: Jack / SM (circle one) list street name and address, provide additional description of location if needed. (See Note No. 1)
____

(CT) & (Telco) Cross Street reference. Direction: ______ ft mi (circle one)
N S E W (circle one) of cross street: ________________________
____

B. SERVICE POINT (terminal pole. manhole. etc.)

(Telco) 1. Terminal Address or Manhole Location (SERVICE POINT), (See Note Number 2)
____
Cable Count (if known)______________________________
5 Pair placed by: OSP Const. ______ or AIM/SS ______ # of feet ___

(Telco) 2. Telephone Company Serving CO (exchange name): ____________

X-FORM, Page 2

(Telco) 3. Common Language Code: ________________________________

C. FIELD VISIT and POINT OF DELIVERY LOCATION:

(Telco) 1. Date of Field Visit:

(Telco) 2. Representative in attendance during Field Visit (list name, title, and telephone number, including telephone area code):

(CT) a. CALTRANS
name: ______________________telephone no:________________

name: ______________________telephone no:________________

(CT) ** SIGNATURE ** agreeing to POINT OF DELIVERY location
____

(Telco) b. TELCO (General Tel. or other)
name: ______________________telephone no:_______________

name: ______________________telephone no:_______________

(Telco) ** SIGNATURE ** agreeing to POINT OF DELIVERY location
____

(Telco) 3. Did the CALTRANS Representative agree to build their conduit directly to the telephone company's SERVICE POINT? (Terminal pole, manhole, etc.): YES: _____NO: _____(if no, See Note Number 3)

(CT) & (Telco) 4. Remarks: ____
____
____
____
____
____

--NOTES--

NOTE NUMBER 1:

Express the POINT OF DELIVERY location in words. The street names and addresses and the “additional description” (footage ties, property lines, etc.) must be the same as shown on the attached sketch (Y form). This information will also be placed on the TELCO service order and will be used by TELCO field technicians to locate the POINT OF DELIVERY during trouble calls. Each sketch must contain any “construction notes” that are pertinent to the location.

TELCO Engineer will distribute both the “X FORM” and the sketch as follows:
1. One copy to TELCO Construction Department
2. One copy to be retained by TELCO Engineer
3. Original copy to TELCO Coordinator
4. One copy to the TELCO Marketing Representative

NOTE NUMBER 2:

TELCO Construction Department or Special Services will place a five (5) pair cable from the SERVICE POINT to the agreed POINT OF DELIVERY.

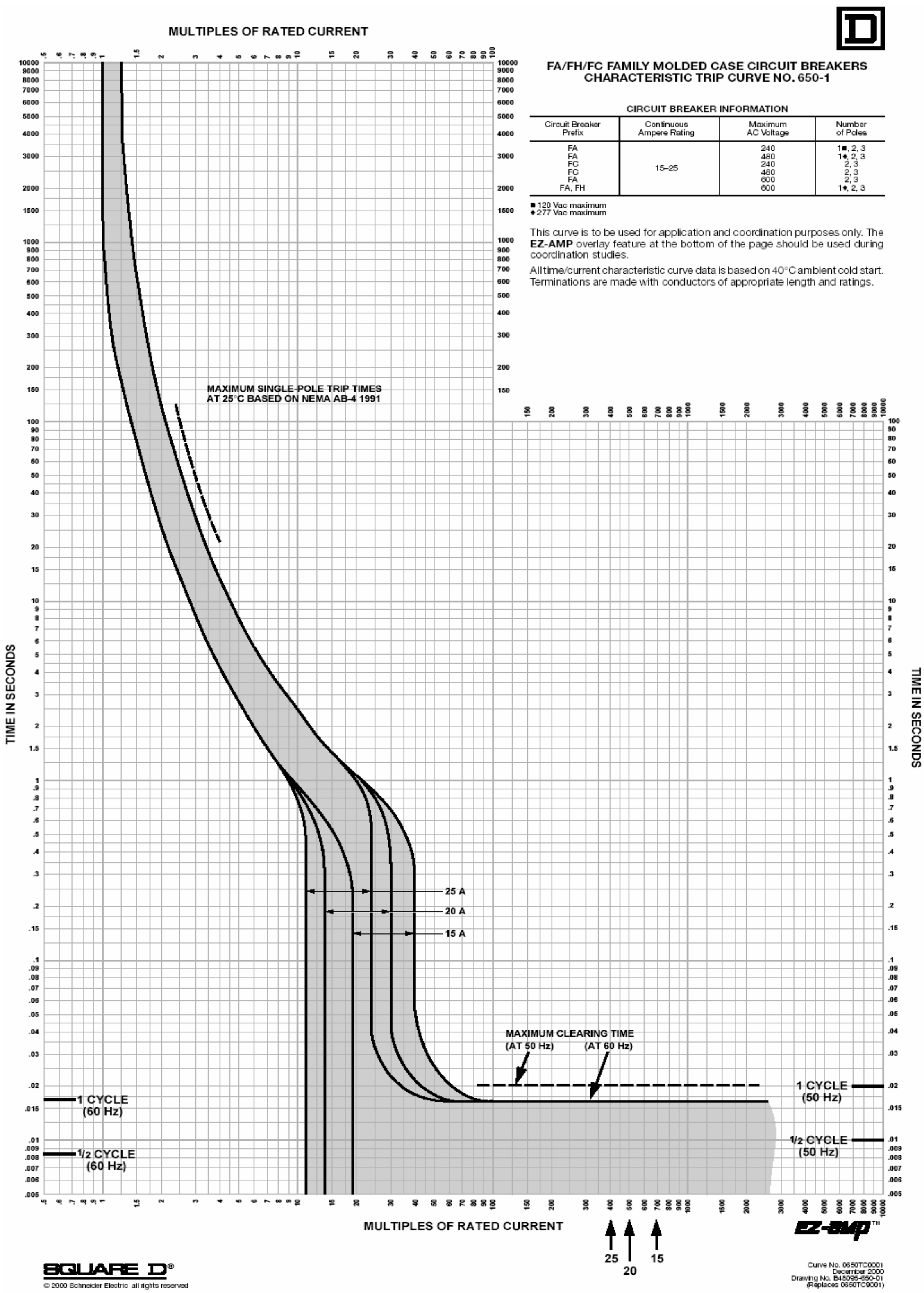
NOTE NUMBER 3:

If “No” the TELCO Engineer must determine if the STATE will be billed for the cost of building telephone plant from the State’s termination point to TELCO’s nearest existing facility. ‘SPECIAL CONSTRUCTION OF EXCHANGE FACILITIES” as guide. Reference PUC Traffic No. A2, Rule No. 36.

NOTE NUMBER 4:

When drawing the information on the attached sketch (Y FORM) please do not use an existing map or plan to draw it upon.

APPENDIX K: Circuit Breaker Curve



**FA/FH/FC FAMILY MOLDED CASE CIRCUIT BREAKERS
CHARACTERISTIC TRIP CURVE NO. 650-1**

CIRCUIT BREAKER INFORMATION

Circuit Breaker Prefix	Continuous Ampere Rating	Maximum AC Voltage	Number of Poles
FA	15–25	240	1■, 2, 3
FA		480	1♦, 2, 3
FC		240	2, 3
FC		480	2, 3
FA		600	2, 3
FA, FH		600	1♦, 2, 3

■ 120 Vac maximum
♦ 277 Vac maximum

This curve is to be used for application and coordination purposes only. The **EZ-AMP** overlay feature at the bottom of the page should be used during coordination studies.

All time/current characteristic curve data is based on 40°C ambient cold start. Terminations are made with conductors of appropriate length and ratings.

Curve No. 0650TC0001
December 2000
Drawing No. B48095-650-01
(Replaces 0650TC9001)

APPENDIX L: Glossary

List of Glossary

Definition	Description
Branch Circuit	A circuit conductors between the final overcurrent protective device and the outlets (load).
Buck/Boost Transformer	A transformer to buck or boost the voltage in a circuit by a small amount to remedy voltage drop problems in lengthy circuits or to feed a specific loads.
Clear Recovery Zone	Unobstructed, relatively flat area provided beyond the traveled way to permit the recovery of cars that accidentally run off the road.
Conduit	A pipe or tube in which smaller pipes, tubes or electrical conductors are inserted or are to be inserted.
Detector	A device for indicating the passage or presence of vehicles or pedestrians.
Electrolier	The complete assembly of lighting standard, luminaire, ballast and lamp.
Feeder	All circuit conductors between the service equipment and the final branch circuit overcurrent protective device.
Flasher	A device used to open and close signal circuits at a repetitive rate.
Ground	A conductive connection, whether intentional or accidental, between an electrical circuit or equipment to earth or to some other substantially large conductive body acting as earth
Lighting Standard	The pole and mast arm which support the luminaire.
Luminaire	The assembly that houses the light source and controls the light emitted from the light source.
Operation Status	Verify operating condition of the electrical system (including detection system) whether working or non-working.
Service	Conductors and equipment for delivering energy from the serving utility to the premises wiring.
Service Equipment	Necessary equipment connected to load end of service conductors to supply a building or structure.
Service Point	The point of connection between the facilities of the serving utility and the premises wiring (location defined by every utility)
Short Circuit Analysis	A calculation to select the proper characteristics of an overcurrent protection device to disconnect an electrical circuit from the source safely.
Signal Face	A part of the signal head provided for controlling traffic in a single direction and consisting of one or more signal sections.
Signal Head	An assembly containing one or more signal faces.

Voltage Drop Calculation	A calculation to determine the voltage lost due to circuit length and load.
Traffic Phase	The right of way, change and clearance intervals assigned to a traffic movement or combination of movements.

APPENDIX M: Acronyms, Abbreviations and Symbols

List of Acronyms, Abbreviations and Symbols

Short form	Full name or meaning
A	Amperes
ac	Alternating Current
ADA	Americans with Disabilities Act
ADN	Advance Digital Network
ANSI	American National Standards Institute
APS	Accessible Pedestrian Signals
AVC	Automatic Vehicle Classification
AWG	American Wire Gauge
BBS	Battery Backup System
CA	California
CCO	Contract Change Order
CCTV	Closed Circuit Television
CCU	Camera Control Unit
CDMA	Code-Division Multiple Access
CDPD	Cellular Digital Packet Data (Wireless, low speed data communication)
CFM	Contractor Furnished Material
Ch.	Channel
CIA	Controller Isolation Assembly
CMS	Changeable Message Sign
Co	County
Const	Construction
CPUC	California Public Utilities Commission
CT	Caltrans
CTCDC	California Traffic Control Device Committee
CTID	Caltrans Identification Number
dB	Decibel
DDS	Digital Data Service
DEPE	District Electrical Project Engineer
DES	Division of Engineering Services
DEUC	District Electrical Utility Coordinator
DH	Detector Handhole
DLC	Detector Lead-in Cable
DOT	Department of Transportation
DSL	Digital Subscriber Line
DSLC	District Signal and Lighting Coordinator
DSU	Data Service Unit
DTCC	District TC Coordinator
DTE	Data Terminal Equipment

DTM	District Telecommunication Manager
DTR	District Telephone Company Representative
DTV	Digital Television
DUC	District Utility Coordinator
DVD	Digital Video Disk (also Digital Versatile Disk)
EA	Expenditure Authorization
EDBC	Electrical Design Branch Chief
EDE	Electrical Design Engineer
EMS	Extinguishable Message Sign
ENT	Electrical Non-metallic Tubing
ESC	Engineering Service Center
ESE	Electrical Systems Engineer
ETW	Edge of Traveled Way
EUSERC	Electrical Utility Service Equipment Requirement Code
EVDO	Evolution Data-Only
EVP	Emergency Vehicle Preemption
FB	Flashing Beacons
FCC	Federal Communications Commission
FDU	Fiber (Optic) Distribution Unit
FG	Finished Grade
FHWA	Federal Highway Administration
FO	Fiber Optic
GPRS	General Packet Radio Service
HAR	Highway Advisory Radio
HAZMAT	Hazardous Material
HDM	Highway Design Manual
HDPE	High Density Polyethylene
HPS	High Pressure Sodium type lamp
HSDPA	High Speed Downlink Packet Access
HQ	Headquarters
Hz	Hertz
IES	Illuminating Engineering Society
IISNS	Internally Illuminated Street Name Sign
ILD	Inductive Loop Detector
ISDN	Integrated Services Digital Network
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System
JP	Joint Pole
Kg	Kilogram
Km	Kilometer
LDD	Luminaire Dirt Depreciation
LED	Light Emitting Diodes
LLD	Lamp Lumen Depreciation
LN	Lane
LRT	Light Rail Transit

Lt	Left
M/F	Master File
MBGR	Metal Beam Guard Railing
m^3	Cubic meter
Mm	Millimeter
MUTCD	Manual on Uniform Traffic Control Devices
MVDS	Microwave Vehicle Detection System
NCHRP	National Cooperative Highway Research Program
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
nSSPs	Non-Standard Special Provisions
NTCIP	National Transportation Communications for ITS Protocol
OES	Office of Electrical Systems
OG	Original Grade
OPPD	Office of Project Planning and Design
PB	Pull Box
PCC	Portland Cement Concrete
PDA	Power Distribution Assembly
PE	Project Engineer
PEU	Photoelectric Unit
PG&E	Pacific Gas and Electric Company
PII	Performance Improvement Initiative
PM	Post Mile
PPB	Pedestrian Push Button
Pr.	Pair
PS&E	Project Specification and Estimates
PUBS	Paper Utility Billing System
PVC	Polyvinyl Chloride
Pvmt	Pavement
RE	Resident Engineer
RPA	Remote Processing Assembly
RPU	Remote Processing Unit
Rt	Right
Rte	Route
RTL	Ready to List
RTMC	Regional Transportation Management Center
RWIS	Roadway Weather Information System
SBI	Slip Base Insert
SFM	State Furnished Material
SIC	Signal Interconnect Cable
Sig.	Signal
SLI	Sensor Lead-in-Cable
SMFO	Single Mode Fiber Optic
SP	Side Mounted Signal for Pedestrian
SPB	Service Payable Branch

SRF	Service Request Form
SSPs	Standard Special Provisions
STC	Screened Transmission Cable
SV	Side Mounted Signal for Vehicle
SVE	Service Equipment Enclosure
TC	Telephone Cabinet
TDC	Telephone Demarcation Cabinet
TEES	Transportation Electrical Equipment Specifications
TELCO	Telephone Company
THHN	Thermoplastic High Heat Resistant outer Nylon jacket
THWN	Thermoplastic Heat and Water Resistant outer Nylon jacket
TIS	Traveler Information System
TMC	Transportation Management Center
TMS	Transportation Management System or Traffic Management System
TOU	Time of Use
TOS	Traffic Operations System
TP	Top Mounted Signal for Pedestrian
TV	Top Mounted Signal for Vehicle
USB	Universal Serial Bus
USDOT	U.S. Department of Transportation
V	Volt
VC	Vertical Curve
V_D	Voltage Drop
VDS	Vehicle Detection Stations
VEU	Video Encoder Unit
VIVDS	Video Imaging Vehicle Detection System
VTCSH	Vehicle Traffic Control Signal Heads
W	Watt
XHHW	Cross-Linked High Heat Water Resistant Insulated Wire
Xing	Crossing
X Sec	Crossing Section
Y	Wye
Z	Impedance (R + jX)
Δ	Delta
°C	Degree Celsius